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IRON AND STEEL ENGINEER

DECEMBER • 1939

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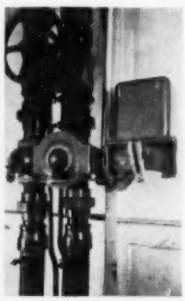

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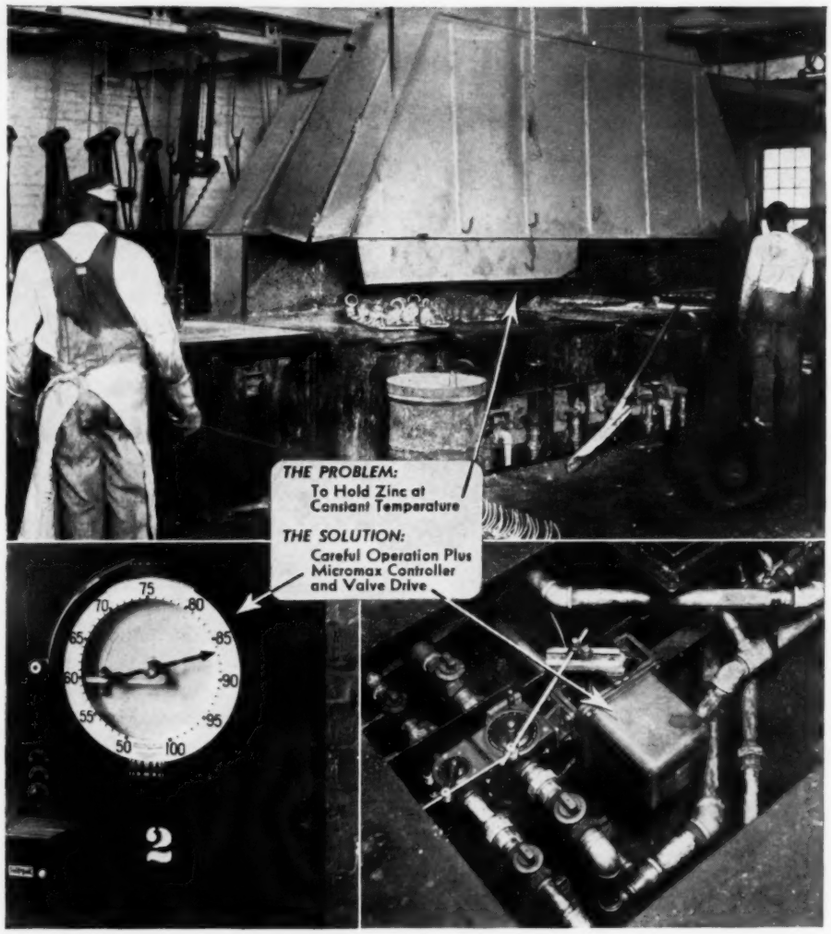
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EC&M NEO-TIME STARTER meets requirements of Limited Generator Capacity

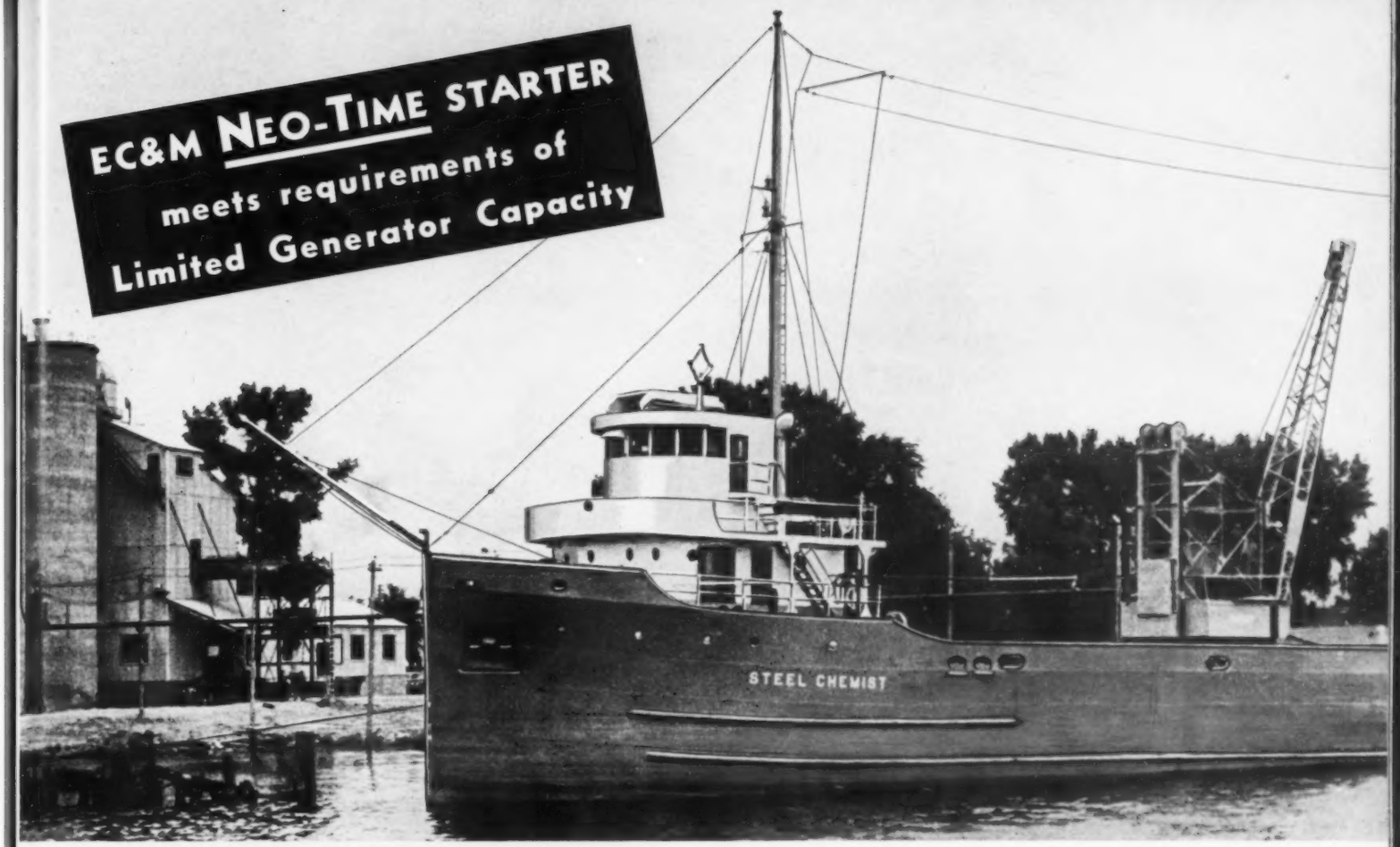

PHOTO COURTESY PIT & QUARRY

WHEN adding a large, electric motor-driven air compressor to this Lake Freighter, it was necessary to keep current peaks at a low value during starting in order not to overburden the capacity of the ship's direct current generator.

For this requirement, the ship owners selected an EC&M **NEO-TIME** Motor Starter of heavy-duty design for the 150 HP, 230 Volt compressor motor. Long-time acceleration on the starting resistors is provided by EC&M **NEO-TIME** Control—a simple, flexible, **definite-time** system, easily adjustable over a wide range.

The Starter, as illustrated at the left with front-door and screwed-on side-plates removed, is a compact, self-contained unit. Starting resistors are mounted in the top of the enclosing cabinet. The **NEO-TIME** unit, with its front-cover removed, is located at the upper right hand corner of the starter-panel. **NEO-TIME**, in this case, is adjusted to provide about 28 seconds time from the instant of starting until the last acceleration contactor closes.

EC&M **NEO-TIME** Control is a sturdy, flexible system of control, for successfully solving . . . acceleration problems . . . industrial timing problems. Put your requirements up to EC&M **NEO-TIME** Control.

EC&M NEO-TIME Control can be designed to provide definite time ranging from a few seconds up to several minutes per step as required. Adjustment is made by simply turning a small dial. Could anything be simpler or quicker!

THE ELECTRIC CONTROLLER & MFG. CO. E&M CLEVELAND, OHIO

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FOR ACCELERATION • FOR INDUSTRIAL TIMING PROBLEMS

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"The grease we had been using left the bearings far too quickly. When regreased at their regular interval, bearings were usually very dry — and appeared badly neglected. They had to be greased more often. Lubrication costs mounted. » » » We switched to TYCOL Green Cast Grease. Such an improvement as we experienced seemed almost like a miracle. Now, bearings are well lubricated even though greased much less often. Because of this better protection bearings give more satisfactory service . . . last longer." » » » It's the extra oil — and less soap — per pound of grease that makes TYCOL Green Cast Grease the outstanding bearing lubricant. It "stays put" even in worn bearings — gives a better film of protection. Why not select the proper TYCOL Grease and oil scientifically engineered to do each job in your plant? A Tide Water engineer will gladly assist. He may save you money and worry. Write for details.

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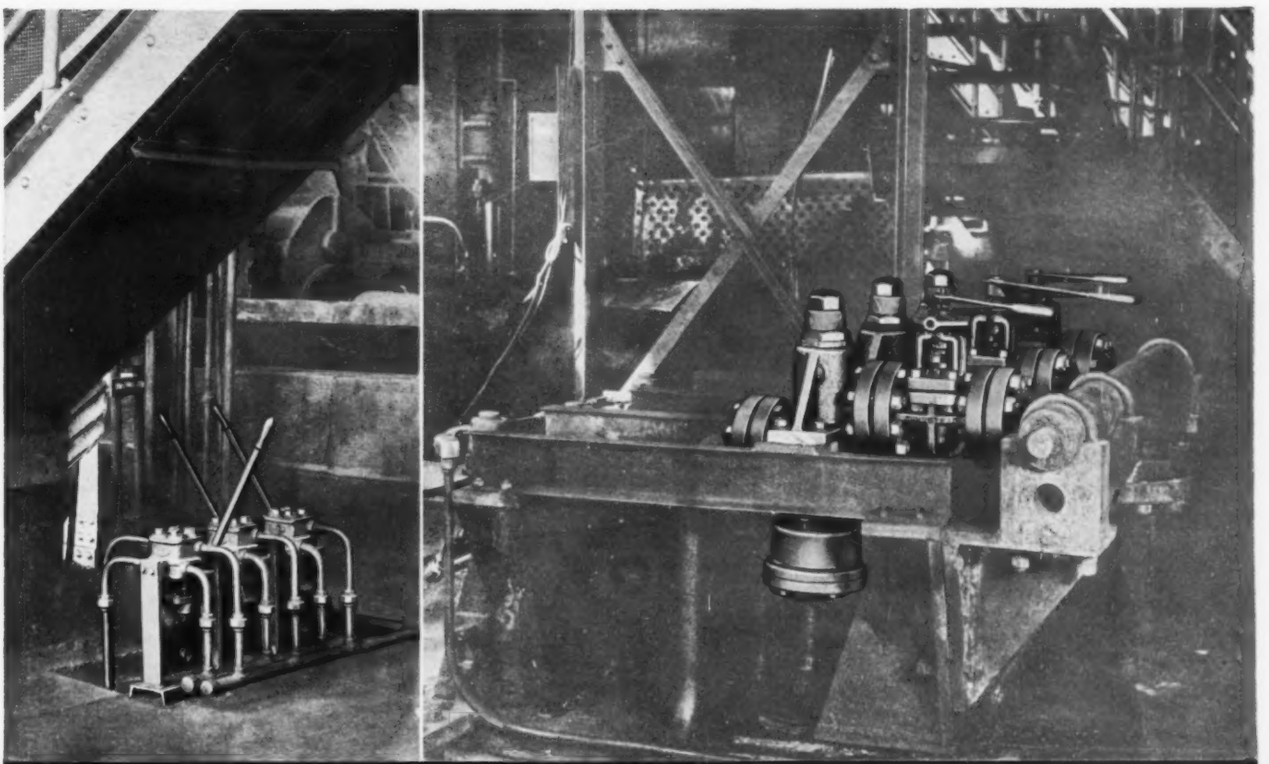
PRODUCTION STEPS UP AND COSTS GO DOWN
WHEN YOU USE HOMESTEAD VALVES



PROTECTED SEAT HYDRAULIC OPERATING VALVES | PROTECTED SEAT SPRAY VALVES | LIFT-PLUG VALVES

Often, users tell us that Homestead Valves are responsible for increased production. For example, a slab mill recently stepped-up production 50%, from 14 to 21 ingots per hour, by installing a roll balance system, and using Homestead Protected Seat Hydraulic Operating Valves as controls.

And users soon learn that in addition to more production, their valve maintenance costs are greatly reduced. For instance, the majority of Homestead Operating Valve records show that these valves give twelve to eighteen months continuous leakless service without even the reversal of a small fibre disc, whereas two or three replacements or repairs were required each week on valves formerly used.

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Let our engineers help with your valve problems; and write for your copy of reference Book No. 38 as a guide in the selection of the right Homestead Valve for your needs.

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LUBRICATED TYPE
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PROTECTED-SEAT VALVES:
HYDRAULIC (B. & O. PAT.) OPERATING
REMOTE CONTROL
HYDRAULIC DESCALING
ROSS AIR SHUT-OFF VALVES
HOVALCO BLOW-OFF VALVES

NEW WAGNER HYDRAULIC BRIDGE BRAKES

HERE ARE A FEW OF THE OUTSTANDING *NEW* FEATURES

SHOE CLEARANCE ARM

1

The shoe clearance arm represents a distinct advance in brakes of this type as it automatically locates the shoe assembly in full release position thereby eliminating the possibility of dragging brake shoes.

ADJUSTMENT

2

Adjustment is effected by two self locking nuts that are in plain sight and accessible to any type of wrench.

PINS AND BUSHINGS

3

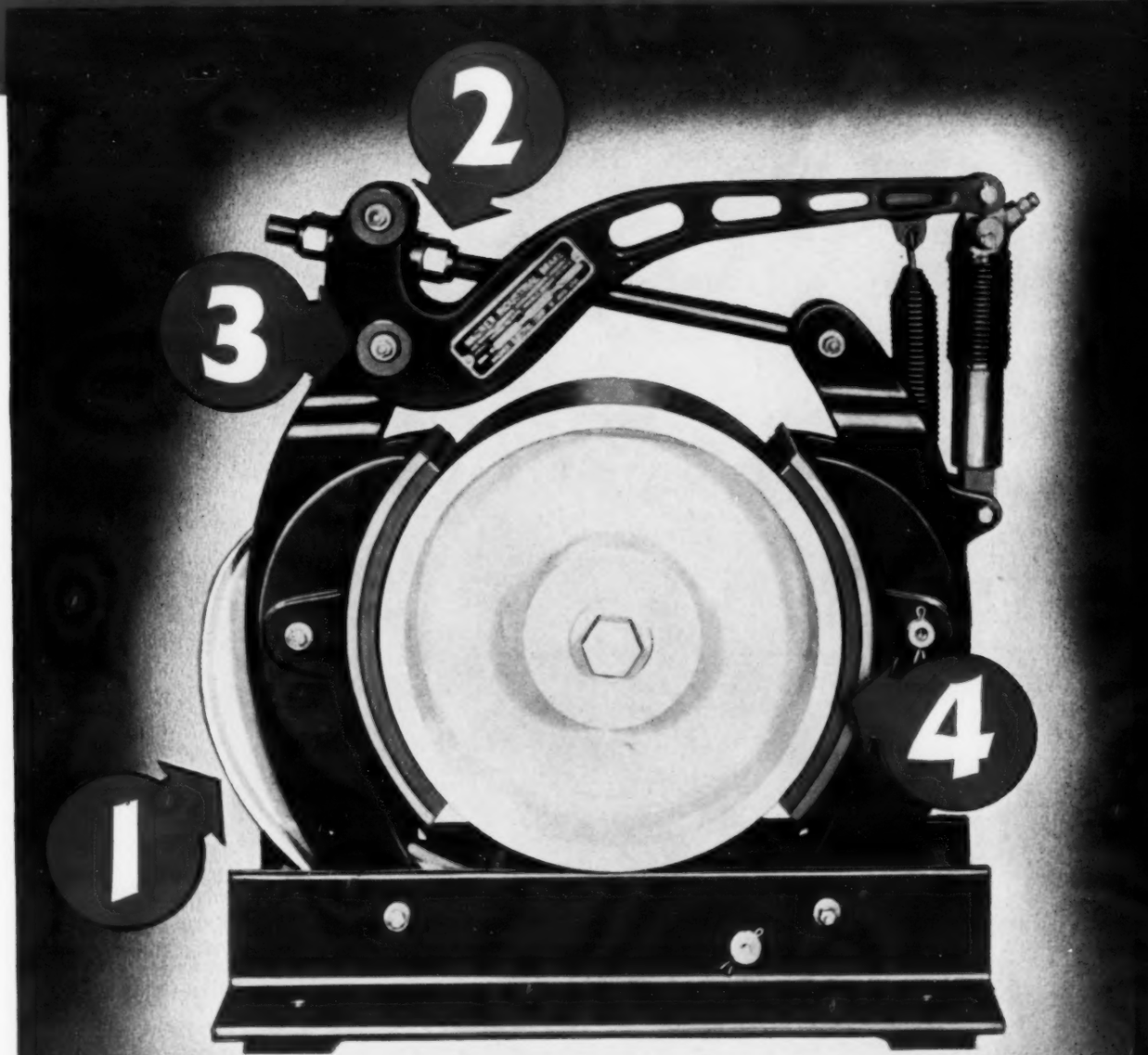
Hardened steel pins are provided at all hinge positions . . . Grease fittings are installed in all pins requiring lubrication . . . All hinge points have ample bearing surfaces . . . Replaceable bronze bushings are employed at points of maximum wear . . . Knurls prevent pin rotation, confining wear to the oversize bearings provided.

All hinge points are held to close tolerances insuring long life under severe service conditions and reducing foot pedal travel to a minimum.

FRICTION MATERIAL

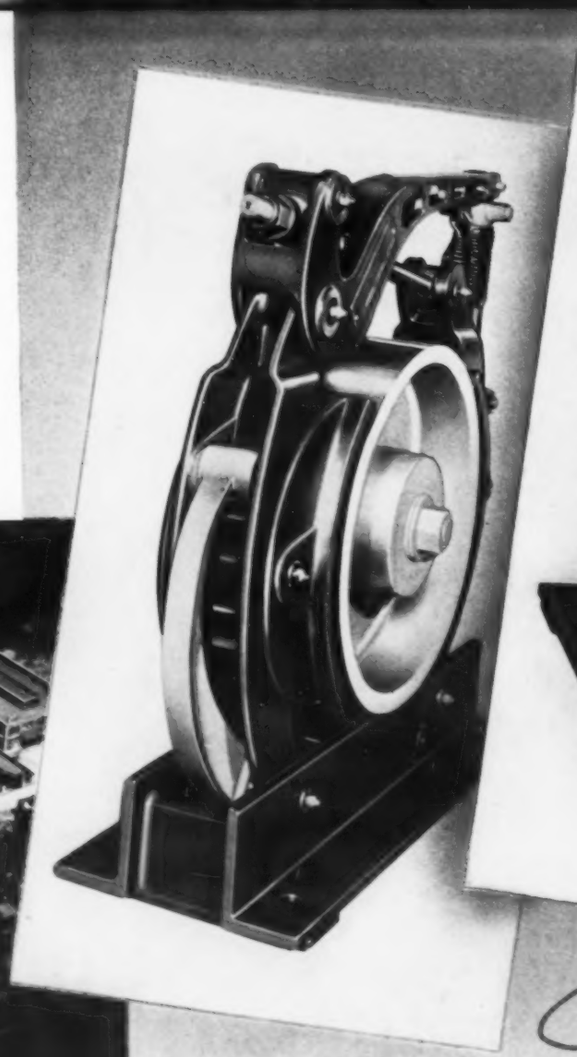
4

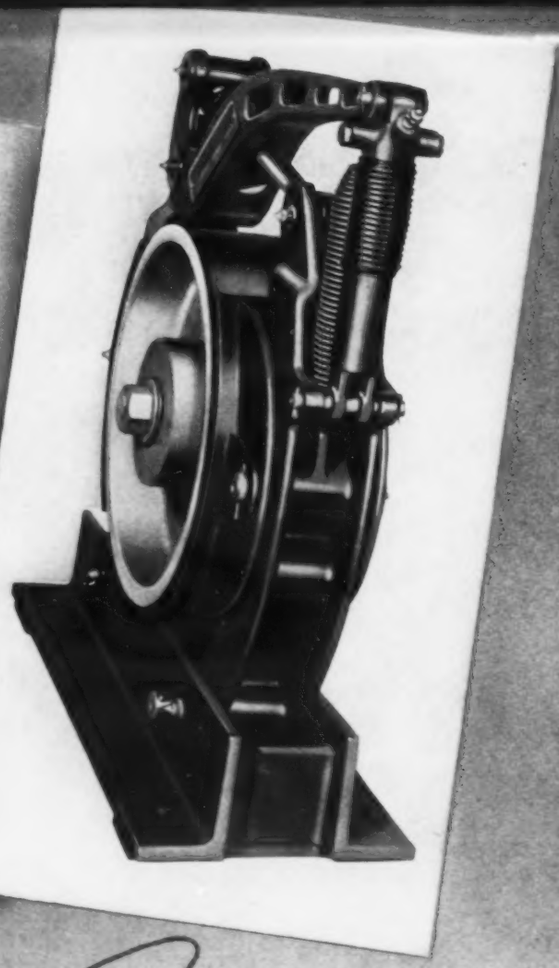
Wagner Jig Drilled Friction Blocks embody the latest advances in friction materials. They provide long life and uniformity of action under the most adverse operating conditions. Scoring is virtually unknown where proper brake wheels are used.



the most adverse operating conditions. Scoring is virtually unknown where proper brake wheels are used.

The WAGNER Plant illustrated below is the home of the new Wagner Hydraulic Bridge Brakes. This modern plant covers more than 23 acres—almost 800,000 square feet of floor space, equipped with the very latest type of manufacturing equipment. Within its confines you will find a staff of trained and experienced engineers, many of whom have given over their entire time to the study and perfection of hydraulic brakes—ever since hydraulic brakes were first applied 15 years ago. It also includes test laboratories and test equipment where every Wagner product must undergo severe tests and meet Wagner standards. The name "Wagner" on hydraulic bridge brakes is your assurance of safety and reliability.





Specify **THE *NEW***

WAGNER HYDRAULIC BRIDGE BRAKES

139-2

Wagner Electric Corporation

6400 Plymouth Avenue, Saint Louis, Mo., U.S.A.

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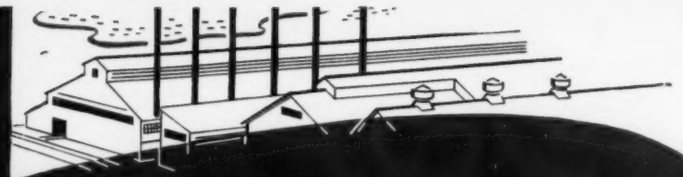
Hagan Type DO Open-Hearth Furnace Pressure Control and typical pressure chart. Notice how accurately the pressure was maintained throughout the day.



Paid for itself IN 65 DAYS

Hagan Open-Hearth Furnace Pressure Control Saves $13 a Day. Increases tonnage 5%

WHERE can you make a better investment than that? Or earn a quicker return on your money? If you need this control and are not using it, you're paying for it over and over again through increased production costs.

Hagan Automatic Furnace Pressure Control was installed on an open-hearth furnace in a large steel mill in the Pittsburgh district. Tonnage was increased approximately 5% per hour due to more even operation. Savings in fuel alone amounted to more than $13 a day. At this rate the equipment paid for itself in 65 days and in a short time paid for all installation costs. Similar results are being obtained from Hagan Control installations in numerous other mills and can be obtained in yours.

Hagan also makes dependable, accurate control for soaking pits, slab- and billet-heating furnaces and any other applications where the control of furnace pressure, fuel-air ratio and volume are important problems. Our engineers will be glad to look over your mill and make recommendations that will lead to lower production costs. Write or call.

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300 Ross Street Pittsburgh, Pa.
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HAGAN *Automatic* COMBUSTION CONTROL

Use BILLETEERS
Save • MEN • MONEY • MATERIAL

COMPARISON OF BILLETEER VS HAND CHIPPING

Comparison of results of hand chipping vs Billeteer

Hi sil mg.—Chrome Vanadium Spring Stock

Stock Sizes . . . . . 4"x4" 5"x5" 6"x6" 8"x8"

Total hours Billeteer operation 1280.

Total chipped on the machine 4967 tons.

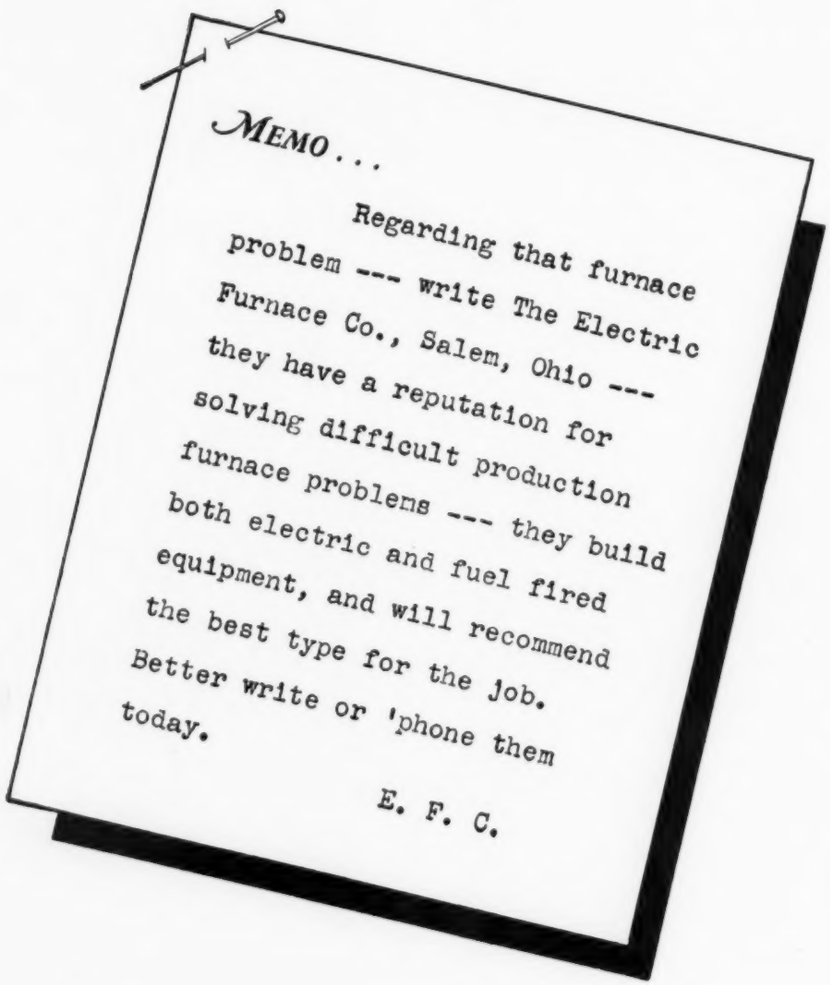
Steel classed as 3½ Hr. per ton for hand chipping.

	Hand Chipping	*Billeteer*
Tons per hour	.35	3.88
Time per ton	3½ Hrs.	.258 Hr.
Output ratio	1	13
Rate per hour	$1.30	$5.00
Cost per ton	$4.55	$1.29

ANOTHER TEST

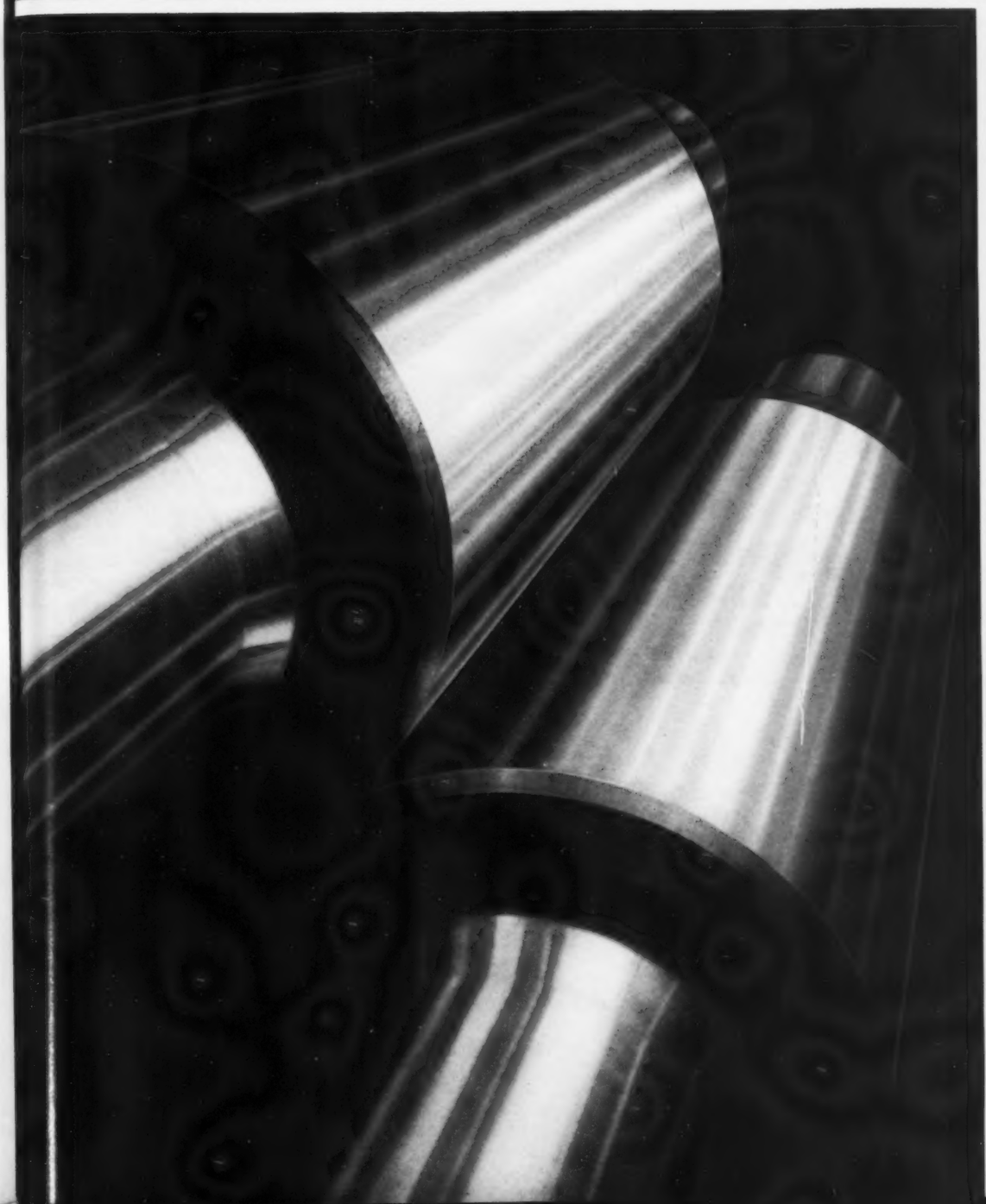
Four billets 4"x4" spring stock were chipped all four sides for half their length by hand, the remaining half was then chipped on the Billeteer. Time of hand chipping was 8 hours. Time of Billeteer 32 minutes. Ratio 15:1.

STEEL EQUIPMENT DIVISION
THE BONNOT COMPANY
CANTON OHIO U.S.A.


MEMO . . .
Regarding that furnace problem --- write The Electric Furnace Co., Salem, Ohio --- they have a reputation for solving difficult production furnace problems --- they build both electric and fuel fired equipment, and will recommend the best type for the job. Better write or 'phone them today.
E. F. C.

The Electric Furnace Co., Salem, Ohio, Builds Gas Fired, Oil Fired and Electric Furnaces—Furnaces For Any Product, Process or Production.

LESS COST *per Ton of Steel Rolled with* PHOENIX ROLLS



The makers of Phoenix Rolls are engaged solely in the manufacture of better rolls and in future planning for still better rolls. Therefore they produce the kind of rolls that only specialization can produce . . . rolls that give a good account of themselves under any and all conditions.

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- Strip Mills
- Blooming Mills
- Slabbing Mills
- Plate Mills
- Rail Mills
- Sheet & Tin Mills
- Rod Mills
- Structural Mills
- Skelp Mills
- Merchant Bar and Billet Mills
- Pipe & Tube Mills
- Non-Ferrous Mills

PITTSBURGH ROLLS
Division of Blaw-Knox Co.
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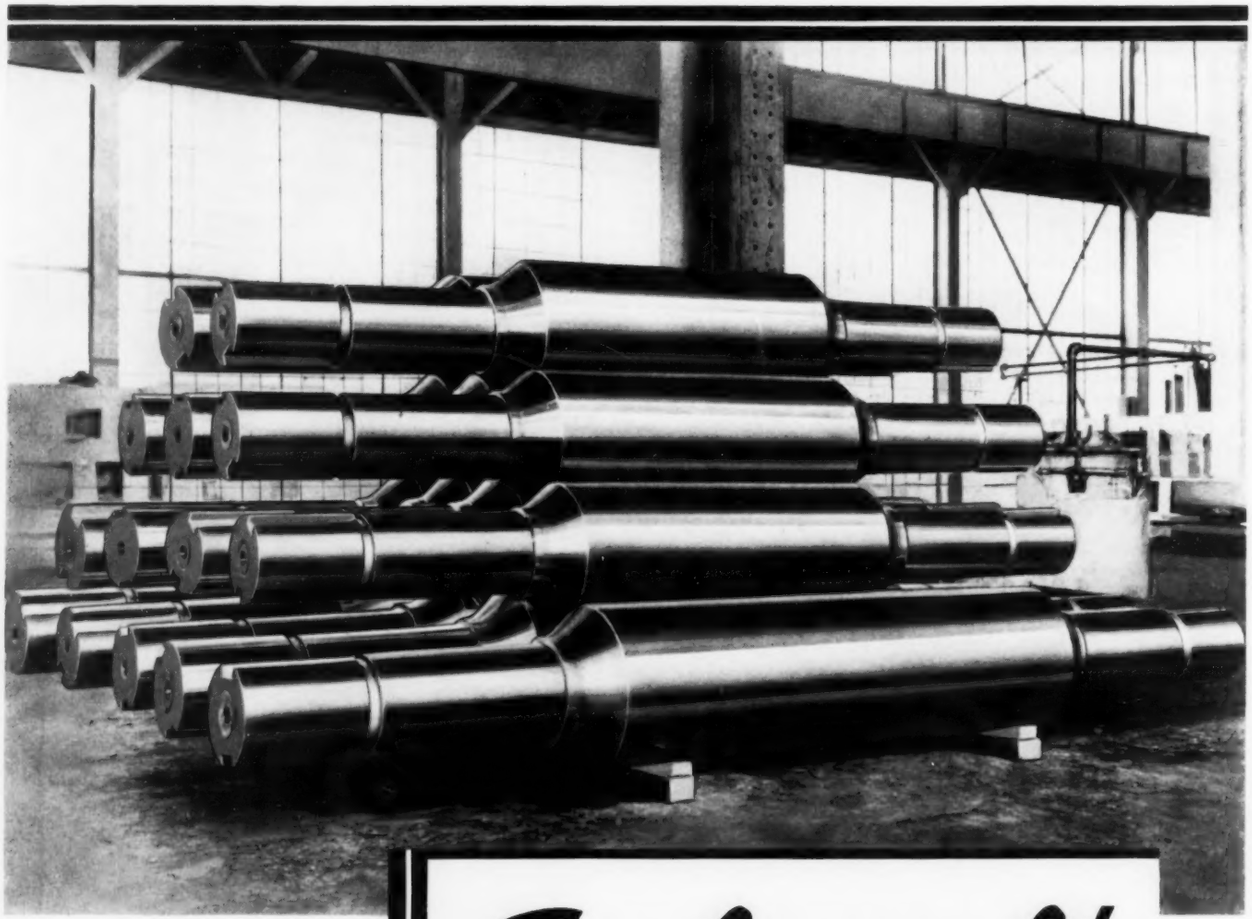
"Steel's Partner"

MESTA

FORGED HARDENED STEEL WORKING ROLLS FOR COLD MILLS



For Longer Life

MESTA MACHINE COMPANY . PITTSBURGH, PA.

Practical ASPECTS of STEEL Making

By C. L. ALTENBURGER, *Research Engineer*
GREAT LAKES STEEL CORPORATION
ECORSE, MICHIGAN

Presented before A. I. S. E. Detroit Section
January 10, 1939

▲ TWO primary raw materials are used in steel making the world over. These are pig-iron and scrap. An extraordinary number of accessory materials are used, with limestone and ferromanganese predominating in basic practice.

Pig iron in itself is a term applied to the product of the blast furnace. Insofar as chemical analysis or physical properties are concerned, nothing is implied by the term as to constancy. On the contrary, pig iron is of extremely variable analyses and physical properties; these provide a basis for its classification and use. Pig iron, in general, possesses a character which it inherits from the ore from which it was smelted. Such personality is of great importance, and in certain cases, dictates the manner in which the steel must be made therefrom and the uses for which the steel will be suitable.

Scrap, never alluded to as junk, is of diverse kinds and analyses. The size and shape of scrap is often as important as its chemical makeup. Variations in either, produce variations in steel making which have far reaching import, both from the standpoint of quality and economy.

Charges for steel making may consist of all ranges of pig iron-scrap mixtures. The particular manner in which steel is made depends greatly upon the proportion of pig iron used. Thus, if we should journey from place to place within the civilized world, visiting all the steel plants established therein, we would find an amazing variety of steel making processes, each operating in a particular manner because of one or more specific conditions peculiar to the region from which the steel plant obtains its primary raw materials, or peculiar to the market which the steel plant is to supply.

Obviously, only a brief and general picture can be presented here. If we focus our attention on the pig and scrap process, using hot metal with the amount of iron in the charge within the range 40–50 per cent, depending upon the grade of steel being made, a comprehensive picture can be presented which will be true on the average.

At the beginning of the heat cycle, a small amount of scrap of a kind that has a large covering power is charged to the bottom which has been cleaned and repaired, and is hot from the heat which has previously been tapped. A definite amount of limestone, or burnt lime is charged on top and the balance of the scrap charge placed over the flux. During the time the scrap is being charged, the furnace is under fire, the scrap is gaining in temperature and its surface is being covered by an iron oxide from the oxidizing components of the gases of combustion. After the scrap has been heated to the correct temperature and its condition is judged to be "right," the hot metal is added. Charging is then complete.

In the event that the scrap is of such physical nature that it presents a large amount of surface per unit of weight, more iron oxide scale will be produced on its surface per pound of scrap charged than when the size

FIGURE 1—Graphical presentation of the effect of nature of charge upon various characteristics of the heat.

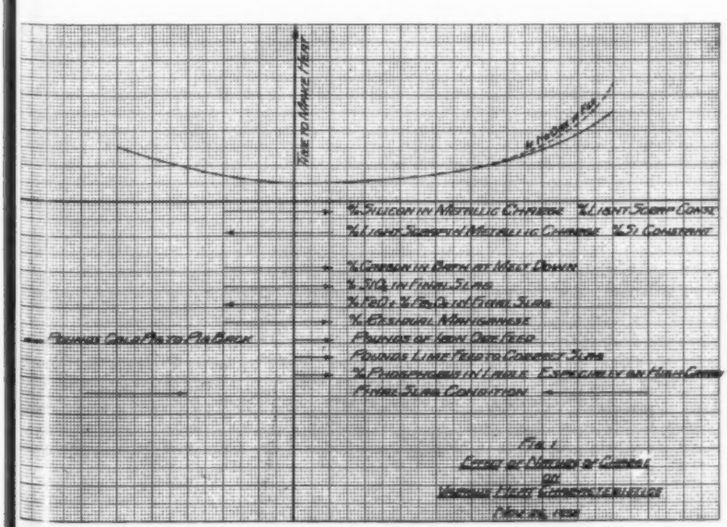
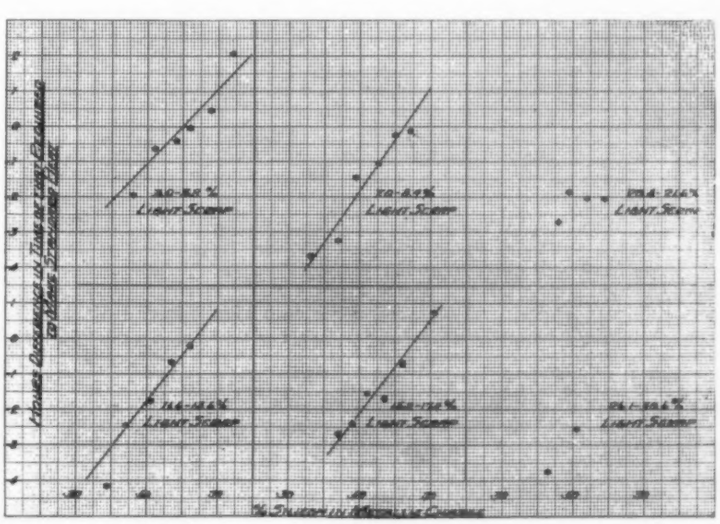


FIGURE 2—Graphs showing effect of the amount of silicon charged on the time of heat.

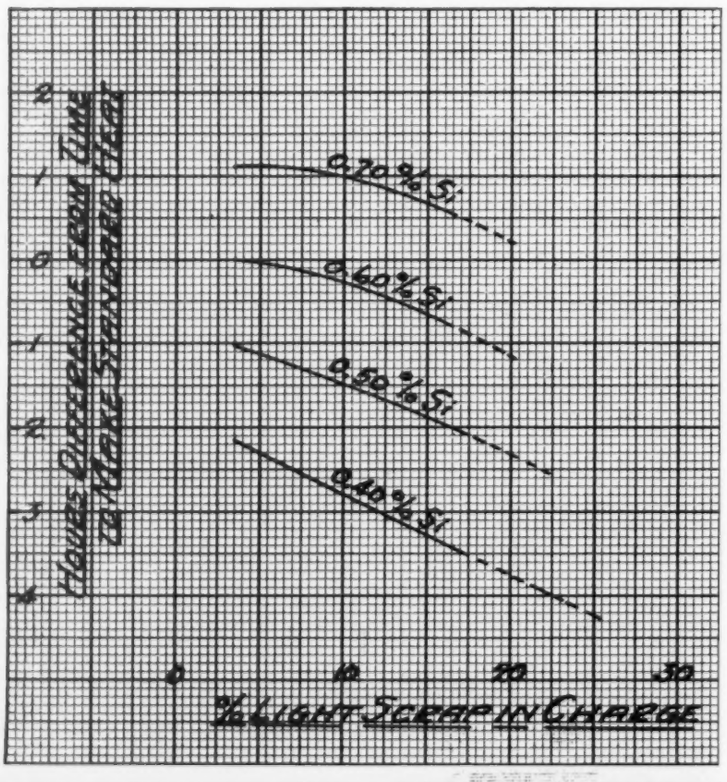


of the scrap is large and heavy. Also, if the method of charging the various kinds of scrap used is such that the more oxidizable scrap is covered, or protected, as for instance by a top layer of cold pig iron, less scale will be produced on the surface of the scrap than if this were not the case. The amount of iron oxide so produced during the period before the heat is melted and under cover has an important bearing on what is to happen later.

If the hot metal charged be high in an element such as silicon which has greater chemical affinity for oxygen than has carbon, such silicon will react with the iron oxide previously produced and, hence, leave less available for the removal of carbon. Silicon contained in the scrap would react similarly.

As a consequence, it follows that the greater the quantity of silicon contained in the charge, the greater will be the amount of carbon contained in the bath at melt down, or at lime up, other things being the same. Also, the greater the amount of light scrap contained in the scrap charge, the lower will be the carbon in the bath at melt down, or lime up, other things being equal. When the carbon at melt down is high, time is required to eliminate it and we find, therefore, that on the average, more time is required to make a heat of steel when the per cent silicon in the charge is high, and with what might be termed small amounts of light scrap. If the amount of light scrap in the charge be greater, with the silicon content of the charge constant, this time will be somewhat decreased. It is evident from the foregoing, that increases in silicon or light scrap work in opposite directions. When bath silicon is very low or the proportion of the total scrap which is light is high, or both, the heat will melt soft, or too low in carbon for the specifications. The heat must then be "pigged" back with either cold iron or hot metal. When the heat melts very soft and, therefore, requires large additions of cold iron or hot metal, the time of making the heat is extended due to the time consumed in these operations, in shaping up the slag, etc. Thus, there exists a balance between the silicon content of the charge and the amount of light scrap which, on the average, will produce the greatest tonnage from any one furnace or will produce heats in a minimum of time.

FIGURE 3—Curves showing the influence of light scrap in the charge on time of heat.



The relationship is shown in Figure 1. The first two lines on the abscissae give what might possibly be termed "primary variables" or "fundamental causes." The other lines along the abscissae present the effects of these primary variables. These effects may in themselves become causes of events which happen later in the heat. Thus, if a given grade of heat is charged with material giving a high per cent of silicon in the charge, and if the amount of light scrap be low, the heat will, on the average, melt high in carbon and will require large quantities of ore feed if the best time is to be made under these conditions. The slag will be acidified from the silica resulting from the oxidation of inordinate quantities of silicon charged and from any silica contained in the large ore additions which must be made; the slag will be in poor condition, containing lumps of lime floating in a fluid, liquid medium which dissolves lime with great difficulty and slowness. The silica in the final slag will be high if uncorrected with sufficient lime and its iron oxide content will be low; the residual manganese will be high and the phosphorus content of the steel in the ladle will be high. If the heat be charged with too low an amount of silicon or a large quantity of light scrap, or both, this series of events is reversed as depicted in Figure 1. Other and numerous characteristics associated with those enumerated could be cited. We have given sufficient of them, however, to present a general picture of the situation.

A few data will be given in further explanation. Figure 2 shows the effect of the amount of silicon charged on the time to make a .65 per cent carbon spring steel. This data was plotted from a survey of data on some 174 heats. As can be seen, the influence of silicon content is very pronounced. In order to make the data more or less free of variables from plant to plant, a standard heat has been chosen in which the silicon content of the charge is 0.60 per cent and the amount of light scrap, or scrap deemed to present a large surface for oxidation, is from 3.0–3.8 per cent of the total charge. On these heats, of course, the proportion of pig iron and total scrap was constant. The figures along the ordinate give hours of time difference to make the heats plotted from that required to make the standard heat, negative numbers meaning less time and positive numbers meaning greater time.

Figure 3 shows the influence of the amount of light scrap in the charge on the time difference for the same class of steel, the data being taken from Figure 2. From these two figures, it is evident that the per cent silicon

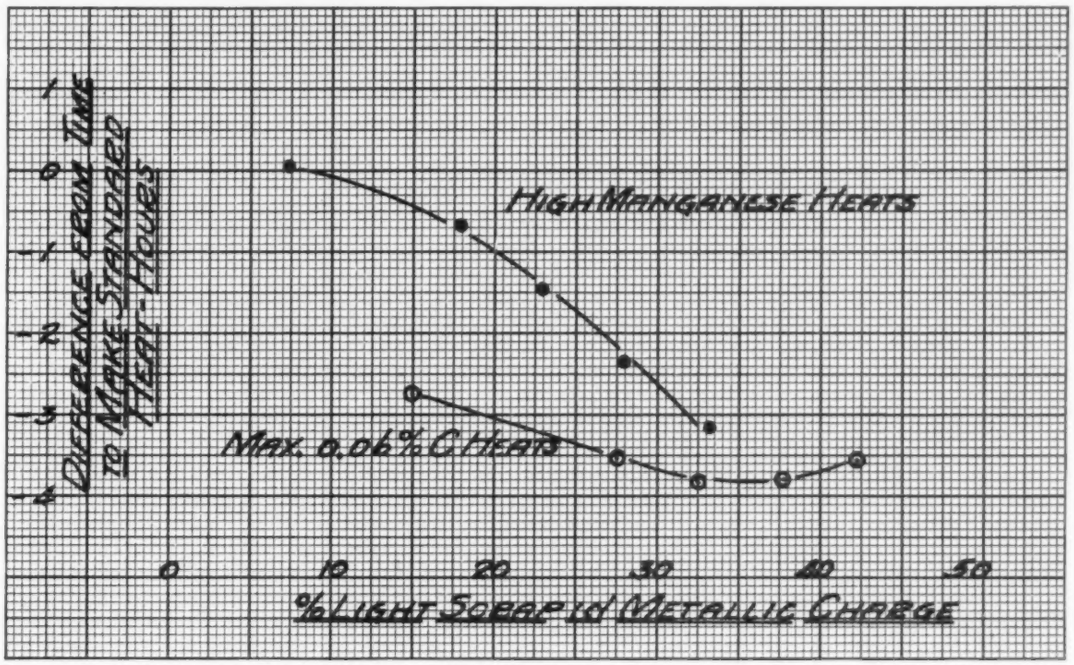
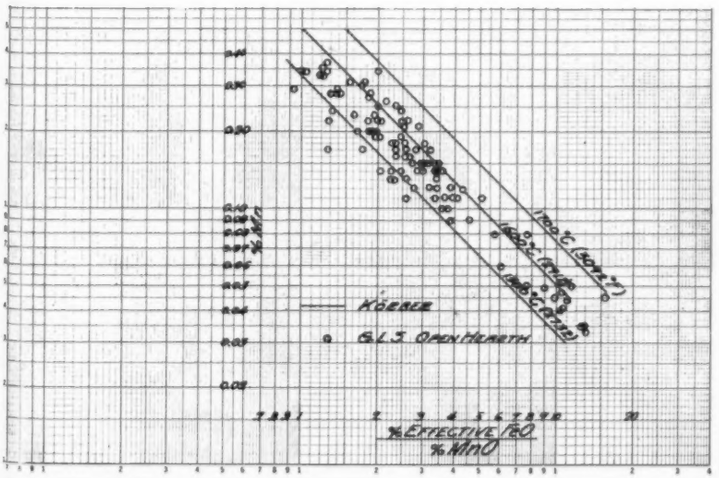
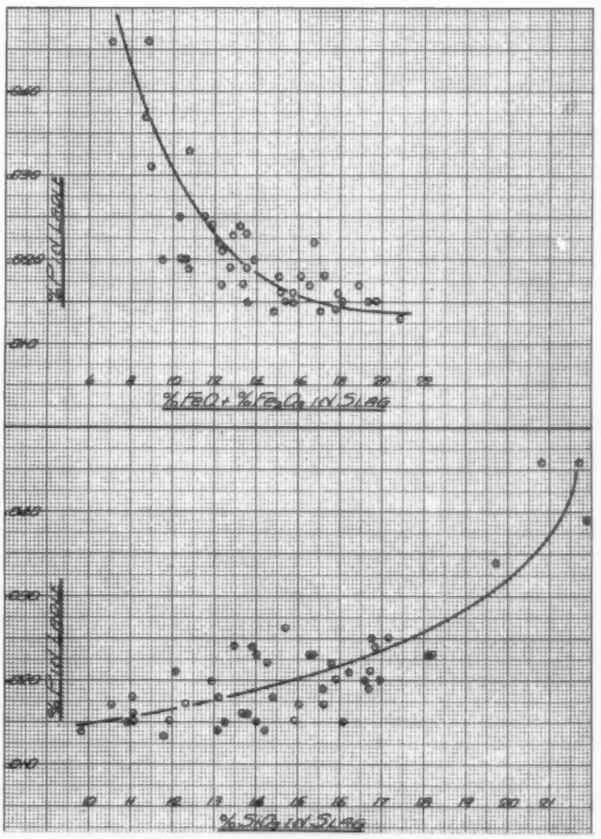


FIGURE 4—Showing the influence of light scrap in the charge on time of heat for several grades of steel.

FIGURE 5—Showing the variation of residual manganese in the bath with varying iron oxide and temperature. (below)

FIGURE 6—Curves showing the relationship between ladle phosphorus and slag analyses. (right)





in the charge is far more influential than the percentage of light scrap.

Figure 4 shows the influence of light scrap on several other grades of steel, the high manganese being made to a ladle analysis of about 0.20 per cent carbon and 1.45 per cent manganese. The maximum 0.06 per cent carbon is open steel. The same standard heat of 0.60 per cent silicon and 3.0 to 3.8 per cent light scrap spring steel is used for the plot of Figure 4. Less pig iron and limestone is used in making the high manganese heats and the maximum 0.06 per cent carbon than the spring steel, the average silicon in the charge in both cases being about 0.50 per cent. The average change in time for the spring steel containing 0.50 per cent silicon from 5 to 20 per cent light scrap is about 1.15 hours as can be seen by referring to Figure 3 along the 0.50 per cent silicon line. For the high manganese steel, this change for variations of from 5 to 20 per cent light scrap is about 1.1 hours, a close check. The open steel is worked somewhat differently, and although the time to make the heat is seen to be a function of the amount of light scrap, the function is different. In the soft heat curve in Figure 4, note that at about 35 per cent light scrap, the time is a minimum, the curve rises for increasing percentages because at higher percentages than 35 the heat tends to melt soft on the average and, hence, the average time is increased.

Inasmuch as the pig iron produced in any one plant will contain an amount of manganese which oscillates about some average percentage, the slags over a given grade of basic open hearth steel will be fairly constant in manganese oxide content on the average. The residual manganese in the bath depends upon the ratio of iron oxide to manganese oxide in the slag and upon temperature. For any given practice wherein the manganese oxide content of the slag is not greatly variable, the amount of iron oxide will cause variation in the residual manganese in the bath substantially as set forth in Figure 5. In this chart, per cent effective FeO is the percent actual FeO in the slag added to 1.35 times the Fe_2O_3 percentage in the slag. This value was used for theoretical reasons to find if the open hearth data fitted equilibrium measurements. If the data be plotted in terms of iron content of the slag, or in terms of FeO plus Fe_2O_3, equally good correlation will be obtained.

Figure 6 shows the relationship which prevails between ladle phosphorus and slag analyses in further justification of Figure 1. The loci of such curves will vary from plant to plant, depending chiefly on the amount of phosphorus contained in the pig iron.

The foregoing places us in a position to interpret other variables in steel practice. For instance, variation in the nature of the fuel used. Producer gas firing is usually thought to produce less oxidation than other types of fuels. Hence, the melt down carbon at a given silicon and amount of light scrap would be higher and the heat time longer, other things being equal, than for other fuels. Also, some fuels produce hotter flames than others, the scrap melts quickly, is under cover faster, and has less time to pick up oxide in which case the curve of Figure 1 would be shifted toward the left. In this case, the design of port and other structural considerations is of importance. If the amount of pig iron be increased, more carbon and silicon is thereby added, the weight of scrap charged is less and, hence, less scrap

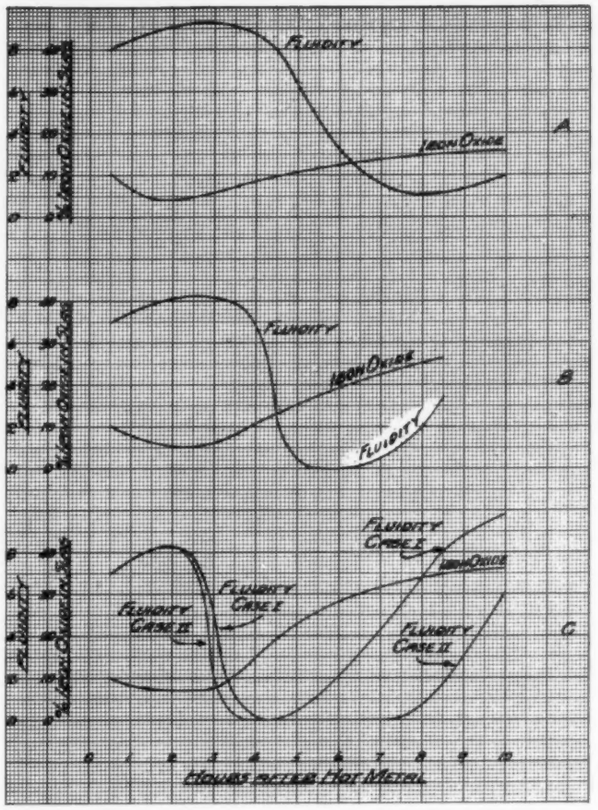


FIGURE 7—Graphical presentation of some of the factors involved in the handling of an open hearth heat.

surface is available to pick up oxide, providing that the total weight of charge is constant. The melt down carbons increase rapidly as the pig iron charge increases in quantity. Variations in carbon content of pig iron also influences the loci of the curve in Figure 1. As can be seen, considerable difference from plant to plant is likely to occur.

The cleaning of the furnace bottom after a heat is tapped is important. Pools of slag left undrained provide iron oxide for the next heat which will modify its later characteristics. Most open hearth operators assert that each heat makes its imprint on its successor. This imprint is the more prominent where widely different grades of steel follow in the same furnace. Similarly, the charging of large quantities of rusty scrap must be taken into consideration.

The first helper or melter who understands his business integrates all these variables, consciously or unconsciously, by watching the appearance of his slag, metal and furnace. A rough picture of the melter's view from his vantage point before the doors of the furnace can be gained by the following and by reference to Figure 7. Three sets of charts are shown therein, labeled A, B and C. In A, the heat has been charged with the silicon content of the charge on the high side. After the hot metal has been added, the small quantity of slag floating over the bath is very acid with silica, and low in lime.

The slag is very thin, as shown by a fluidity reading taken by measuring the distance the slag will run through a horizontal hole drilled in a cast iron block. The iron oxide content of the slag is higher than it will be in an hour or more. As soon as the scrap is melted, the lime begins to rise, creating the lime boil. The lime reacts with the silica in the slag, forming less fusible compounds and the slag begins to thicken and become more viscous. In the chart A, the slag does not become as heavy as in cases where the silicon content of the charge is lower, the lime dissolves with difficulty due to a coating of dicalcium silicate surrounding the floating lump of lime which reposes in a liquid phase of fair fluidity. Because of this difficulty, the lime is said to be "hard," the heat "phosy" because the bath is high in phosphorus. The melter recognizes the need for more lime and charges some through the furnace door to correct it. He has a difficult job in this heat because the lime is hard to dissolve. The heat is high in carbon and needs inordinate quantities of ore feed and if the silica is high in the ore, the condition is further aggravated. The time to get the carbon down and shape up the slag is long. Care must be taken not to get the metal too hot as the heat has a tendency to come up on the warm side. The finishing slags are likely to be relatively heavy and low in iron oxide and the appearance dirty, with numerous small lime floaters.

In cases where the silicon content of the charge and the proportion of light scrap is "just right," the same glossy slags just after hot metal are obtained as before. When the lime comes up, the slag thickens more rapidly (see B) and attains greater viscosity than in the previous case, due partially to the smaller weight of silica to be fluxed and to the greater amount of iron oxide in the slag which permits quick solution. The carbon melts low enough to require a moderate ore addition, the heat does not have to be fought to keep the temperature of the bath down, the slag becomes creamy and homogeneous, finishes with intermediate fluidity with an iron oxide content higher than in the first case. This heat is a "natural."

In C, the amount of silicon in the charge is low and the amount of light scrap is high. The acid, fluid slag just after hot metal thickens rapidly due to the small amount of silica to be fluxed and to the larger weight of iron oxide available to put the lime in solution. If the hot metal addition has been late, the lime is likely to rise in a mass in which case a heavy mat-like slag will persist for some time as indicated in case II of chart C. In this case, the carbon may be too low before the slag is in shape and pig iron will be added to bring the carbon up and to allow time for slag conditioning. Where large additions of iron have to be made, the time to make the heat will be increased. Finishing slags will be homogeneous but thin and high in iron oxide. In case I where the hot metal has been added at the regular time, the slag thickens rapidly when the lime starts to rise, goes into solution very rapidly, at times missing the extremely thick, short stage as shown in the curve for case I. After the minimum fluidity stage has passed, the slag thins quite quickly, the operator must fight to keep his heat warm, especially in sluggish furnaces, the melt down carbon being low may require pig iron, and if the amount of pig required is large, the heat time may be increased. Finishing slags are usually very thin and homogenous.

These cases and illustrations are typical. It will be appreciated that all stages in between these typical cases are encountered.

Slag conditions are important from both an operating and a quality standpoint. Excessively thin, high iron oxide finishing slags are corrosive on the furnace lining, sometimes cut off stopper rods before the heat is teemed into the molds, produce highly oxidized steels and are in many ways undesirable.

Deoxidation procedures in making killed steels and the time required to tap both killed and open steels have an important bearing on the characteristics which the finished steel will possess.

Heats which are excellent as they lie in the furnace just prior to tap may not produce the most desirable properties in the finished condition because of happenings during the tapping operation, one of the more important variables is the time required for tapping.

Much could be said about teeming conditions, mold contours, mold preparation and the like. The quality of the finished steel will depend as much upon subsequent practice as upon melting practice itself. Sufficient material has been given herein, however, to show the great attention to detail, however small, which must be given by the steel maker to obtain the greatest quality at the smallest cost.

A. I. S. E.
DISTRICT MEETINGS

PHILADELPHIA SECTION

JANUARY 6, 1940

"Modern Trends in Steel Plant Power Generation," by H. U. JOHNS, *Mechanical Engineer*, Bethlehem Steel Company, Lebanon, Penna.

Engineers Club, 1317 Spruce Street, Philadelphia, Penna.

PITTSBURGH SECTION

JANUARY 15, 1940

"Improvements in Galvanizing Plants and Practice," by NELSON E. COOK, *General Superintendent*, Galvanizing Operations, Wheeling Steel Corporation, Steubenville, Ohio.

Cardinal Room, Wm. Penn Hotel, Pittsburgh, Penna.

METAL *Spraying* PROCESS *in* MAINTENANCE *Work*

By J. G. MAGRATH
Applied Engineering Department
AIR-REDUCTION SALES COMPANY
NEW YORK, NEW YORK

Presented before the A. I. S. E.
Philadelphia Section, April 1, 1939

▲ IN plant maintenance the scope of the metal spray process is not nearly as limited as in the field of mass production. Further, with the fundamentals of the process fully known and the proper procedure adhered to, successful applications are the rule. It is true that the process was often promoted for impracticable applications and the predictable failure naturally resulted in placing all metal spraying in ill repute. However, the accumulated experience of those sincerely interested in its development, is now available and there appears a definite field wherein certain mechanical and atmospheric corrosion problems are most satisfactorily solved with sprayed metal.

Expensive machine parts, turned shafts, crank shafts, shafts of armatures, turbines, transmissions, impellers, conveyors, stokers, brake cams, worms, jacks, propellors, wheel spindles, piston rods, pump rods, axles and studs may be safely built up to their original dimension on the wearing, bearing or journal surfaces with a metal of equal hardness, characteristics and wearability to that of which the part is made or of greater hardness or different characteristics when such are desirable. Such parts, considerably worn and ordinarily of only scrap value may be salvaged for a small fraction of their original cost.

As an example, one large motor transport company obtains one and one-half to two times the wear from the metal sprayed built-up surface on crank-shafts than received from the original surface. In this and comparable instances, the longer wearing life is attributed to the higher carbon content metal surfacing, often 1.25 carbon, and the greater surface porosity of sprayed metal which, having thousands of minute surface air cells, provides for an equal number of minute oil bearing

FIGURE 1—Micro-photograph of sprayed molten iron on machinery steel (x 100) (below)

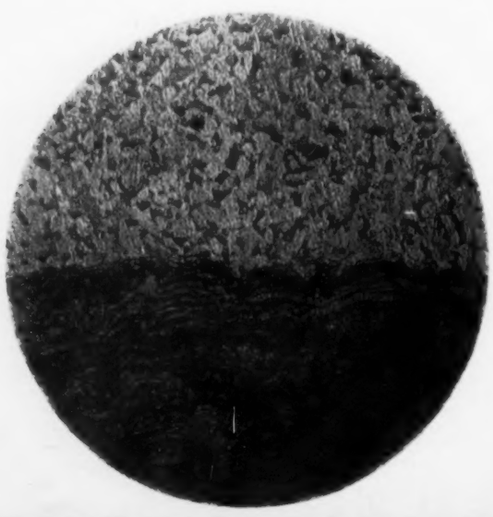


FIGURE 2—Tanks may be lined with zinc (.008 in. or 4 oz. per sq. ft.) to eliminate scaling and corrosion.

cups. As no excessive heat is applied to the part during the process no injurious strains may develop, and there is no danger of distortion. This is proven in that an armature shaft may be built up without stripping and rewinding.

Rolls, large and small, which are not subjected to great pressure or high temperature, such as dryers, printing paper and food presses, hydraulic rams, air pistons and cylinders may be resurfaced completely or recess defects filled in. Patterns, molds, slides and flats may be restored to their original dimensions.

Iron and steel tanks, vats, cleansing and degreasing containers may be metal sprayed to provide corrosion resistance. Aluminum, zinc and cadmium in the anodic series, of a .008 to .015 inches thickness as required will act as an inhibitor of corrosion. Aluminum and zinc do not corrode progressively. Their corrosion causes a protective layer of salts to form like a scab over the wound blocking further deterioration.

Aluminum and zinc are employed as an inhibitor of action from ordinary seacost and lightly laden industrial atmospheres, mild acid solutions, mineral and crude oils, refined oil products, food products and vegetable oils. Cadmium is recommended where salt water and brine solutions are encountered. Tin, lead, brass, bronze, copper, monel, nickel and nichrome, all cathodic to iron, furnish mechanical protection only to iron and steel. Therefore, to provide corrosion resistance, the coating must be sufficiently thick, .020 to .050 inches, to the point of being practically impervious. Lead is used for seacoast and heavily laden industrial atmospheres, brine and acid solutions. Tin is preferable for food and oil products. The monel, nickel and nichrome series provide both corrosion resistance and wearability on running shafts and other parts subjected to sea water, brine and other corrosive liquid solutions.

Prior to spraying, the base metal must be properly prepared by blasting with an abrasive having sharp cutting edges such as angular steel grit. The blast nozzle is pitched at various angles so that undercut caves and overhanging crags are developed. These act as keys and provide anchorage for the minute molten metal particles projected from the spray gun, which upon impacting the surface, flatten and shape themselves to the roughened surface forming an interlocked mass of stratified layers. Metal-sprayed metal is partly pervious. Voids due to the presence of oxides and absorbed gases exist. Although each particle is comparable to cast metal, the mass no longer contains cast metal elongation ductility and tensile strength. However, the qualities of compression, wear resistance, hardness and corrosion resistance exist to sufficient extent to answer the purposes for which the process is recommended.

When an area has been prepared for spraying, it must be kept clean from grease or dirt and must be sprayed before oxidation of the surface occurs. When spraying flat surfaces, tanks and other vessels, a distance of not more than eight inches between the gun nozzle and the subject is maintained, the nozzle being directed full force to the work, moving the gun in a left to right direction and vice-versa. As a rule the natural finish of sprayed metal applied over a blast cleaned surface is satisfactory for corrosion resistance application. But, when required the sprayed area may be

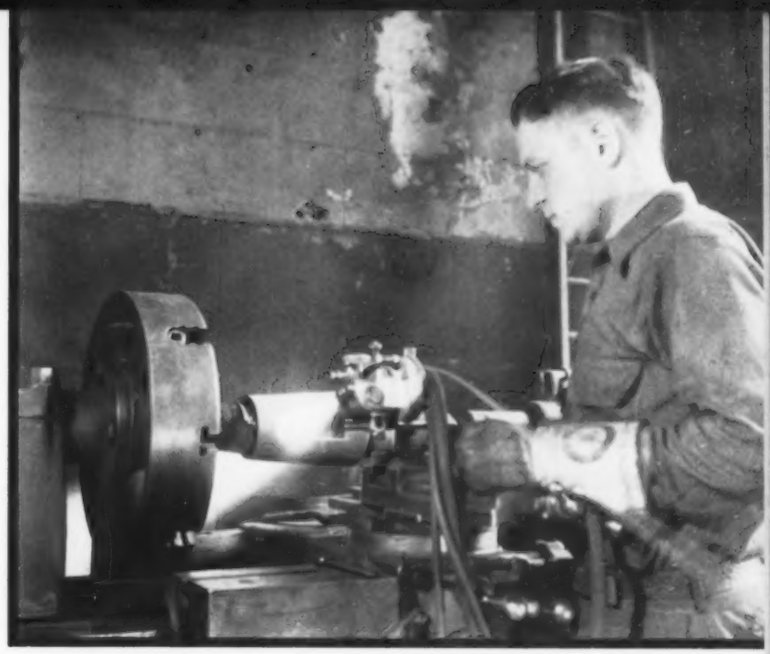


FIGURE 3—View showing spray application of stainless steel to stop-cock.

FIGURE 4—View showing the adding of $\frac{1}{8}$ in. on the radius of a coiler roll, using sprayed phosphor bronze.

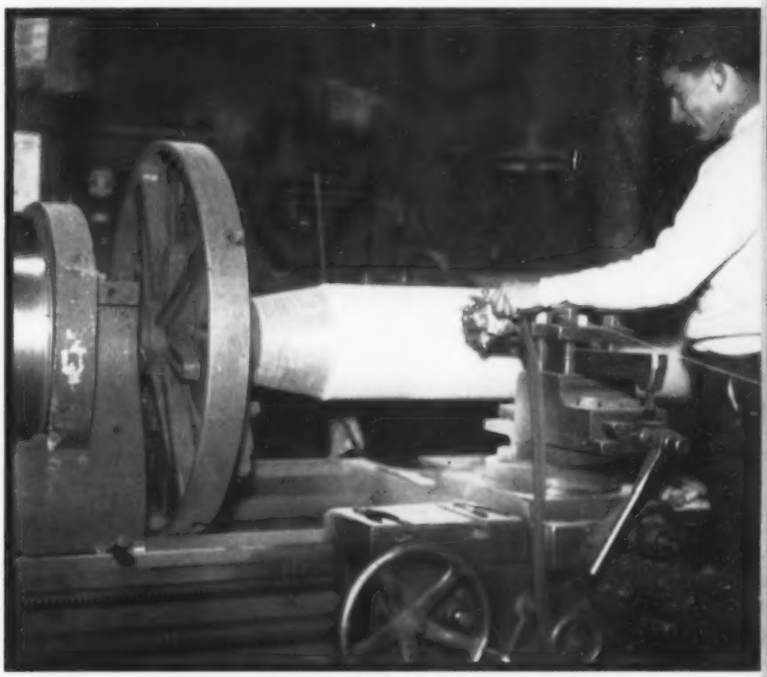


FIGURE 5—Bearings and press fits of this gear-reducer shaft were restored to original dimensions by spraying high carbon steel.

wire brushed, surface ground, buffed or polished. Care must be taken during the spraying operation to insure against overheating the surface as such will cause the metal coating to expand and break its bond to the base.

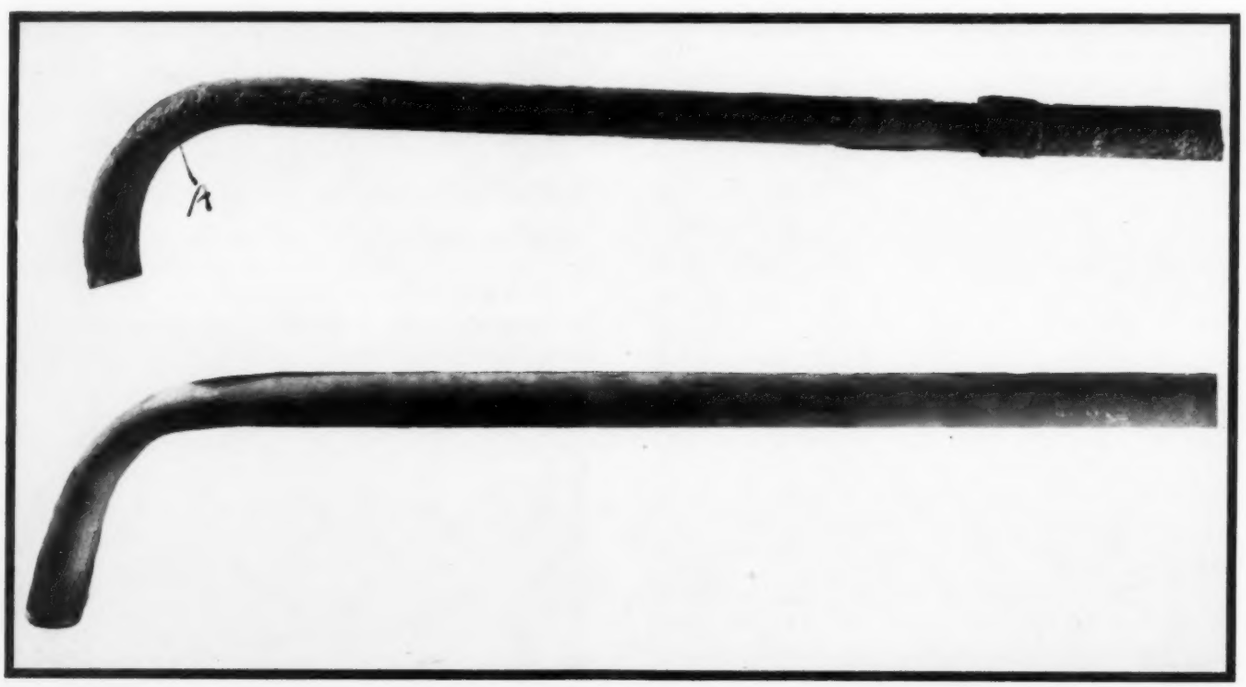
Cylindrical objects such as shafts, studs, rods, spindles, etc., may be rough threaded instead of blasting. The threading tool is set well below center so that a torn thread is obtained. A consistent rule may be applied for the building up of shafts, spindles, journals or similar parts. A minimum foundation thickness of .020 inches, on the radius, of sprayed metal, below the dimension of greatest wear and above the bonding surface, must be provided. The part is set and centered on a lathe and turned down accordingly. This surface is then roughened either by blast cleaning or rough threading as was described. Spraying then proceeds without overheating the base above 200 degrees F. The part is built up above the finishing dimension for a thickness .020 inches on the radius for wet grinding when higher than 0.40 carbon steel is used or .030 inches on the radius for turning when 0.40 carbon or lower content steel is sprayed. Where practical, wet grinding is preferable. A high finish may be acquired by using wetted emery.

Where cylindrical shapes are worn "out of round", measurements are determined upon the side that is least worn and the part is turned down to provide the minimum .020 inches foundation thickness before recommended. After roughening, the side that is most worn is built up to provide an approximately true round. The part is then revolved and entirely built up to full dimension. This procedure applies when cylindrical parts are worn to a lengthwise taper. A minimum of .020 inches foundation thickness must be maintained.

In building up key ways, of the walls and edges are square and without damage insert a hard wood block (or carbon) for the full length of the key way. Allow the block to extend well above the surface of the proposed metal spraying and chamfer the vertical side in order to allow the metal spray to contact the innermost corners. Then build up the metal to the required dimension. The subject is ground or tooled leaving the block in position and working through it. After having obtained our dimension we carefully remove a "V" wedge from the center of the wooden key way for its full length, then carefully remove the remaining side wedges and finish the overhanging edges square with the key way. If the edges of the key way are broken down, such indicates that there is considerable strain on the edge of the key way due to either sudden braking or other harsh handling. In this case build up the edge of the key way with a bead weld obtaining a fusion at this point of greatest strain. The balance of the surface is roughened and built up with sprayed metal finally finishing as above outlined over the entire surface and finishing the inside of the key way square.

Blow, sand and gas holes in castings or other natural or accidental defects in castings or machine parts may be filled in with this process. In the case of castings containing sand or blow-holes, first make a metal shielding plate with various size holes cut therein as well as shaped. The nature of a sand or blow-hole is very often such that the superficial hole appearing on the surface becomes greatly enlarged beneath. Therefore, when such is found to be the case, break the top skin and expose the full area as much as possible. Protecting the balance of the surface with the metal shield, blast clean the accessible area of the hole and fill in with sprayed metal taking care not to overheat. This shield is removed and the surface is ground flush with

FIGURE 6—Spray pond tubes. Upper tube painted with red lead, rusted through at A. Lower tube sprayed with molten zinc, showed no deterioration.



the base object. Filling in of crevices and cracks is done in like manner.

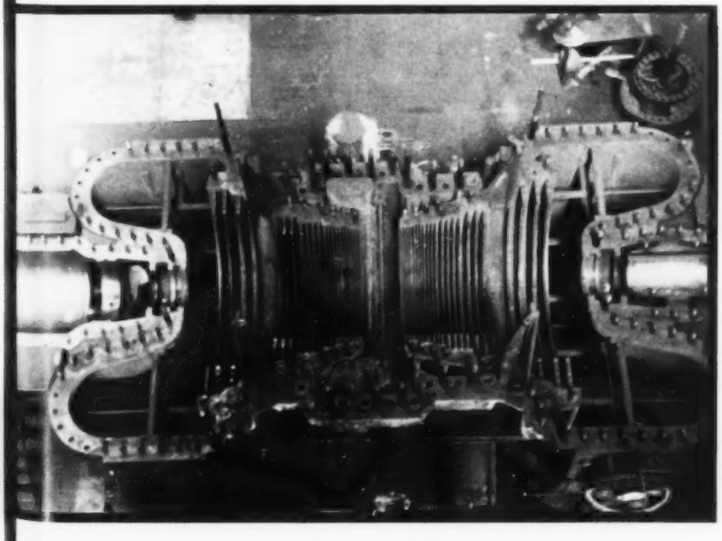
Often we find porous conditions in castings of different metals, particularly cast iron. This problem is solved by metal spraying the casting completely with approximately 0.010 to 0.012 inch of zinc, after fully blast-cleaning the part.

In the maintenance of wrapping, packaging and automatic machinery, the passage of products results in depressions in slides and other flat surfaces. These are filled in by treating similarly to the ordinary mechanical build-up. The area that is worn is machined out to at least 0.020 inch below the depth of greatest wear. It is blast cleaned and sprayed with the proper metal to about 0.020 inch above the finished dimensions. This surface may then be ground flush. As a rule, where allowable, a filling-in metal that is harder than the base metal is used to provide longer life.

The forming edges of pressed sheet metal dies are subjected to considerable edge strain. Metal coatings will not, due to the nature of their structure, withstand sharp impact, squeeze nor edge strain. Where such conditions prevail the fusion of metals obtained by welding is necessary. For instance in the problem presented us by the base-die of dies used for forming dishpans. In this case there was the need to restore the surface contour by building up with metal spray. This problem was solved by placing a bead weld around the edges subjected to strain. The basins then formed were fully blast cleaned as well as the welded area and built-up with sprayed metal. The entire area was surface ground without overheating, to the correct contour.

In the application of sprayed metal to maintenance problems, the fact that metal can be sprayed and that an available laborer can operate the apparatus is not sufficient. An intelligent analysis must be made, in the case of mechanical wear, of the reasons for the wear, the amount of thickness to be provided for future wear and of how wearability may be increased, by the choice of the proper metal. In the case of corrosion, the corrosive agent should be fully studied and then before spraying a study should be made of the comparative costs of a resistance coating of sprayed metal and either a replacement of the unit or, if a vessel, the lining of same with a metal providing the maximum resistance to the corrosive element. In every case, on all subjects, the conditions to which they have been subjected, their present condition and their future use will determine whether or not they are fitting subjects for metal spraying. Further it is useless to metal spray unless mechanically ideal conditions, as herein described, are provided.

FIGURE 7—Blade tip clearance areas of this 20,000 kva. turbine housing were sprayed with stainless steel, preventing further deterioration.



DISCUSSION

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L. F. COFFIN, Superintendent, Mechanical Department, Bethlehem Steel Company, Sparrows Point, Maryland.

W. J. REA, Assistant Superintendent of Maintenance, Bethlehem Steel Company, Bethlehem, Pennsylvania.

G. J. WALZ: Located in the main electrical repair shops of our Steelton plant, we have one of these metal spraying machines, about which Mr. Magrath has given us so much valuable and instructive information This machine has been in operation now, roughly about six months, and, while we have had a very fair measure of success with it, Mr. Magrath's paper has demonstrated most convincingly what we have frequently been told, namely, that this machine has a very wide field of usefulness, outside of spraying on steel, which is the only use to which we have put it, so far. We have, however, been receiving complaints from the men who work at and near this machine. Now, with a view to taking some action towards satisfying these complaints, there are two questions which I would like to ask of Mr. Magrath, considering the metal spraying machine only, since there is no sand blasting equipment in our electrical department shops.

First, is the dust, and are the fumes, which are

thrown off, really downright injurious to human beings or are they merely annoying and discomforting?

Second, what does he consider the most effective method, based on his experience, which we should use, to protect these men from this hazard?

Our machine happens to be spraying just now an exceptionally large job, a worn piston rod taken out of a gas engine rated at approximately 6,000 horsepower. If our worn piston rods can be successfully reclaimed in this manner, this would probably constitute the most outstanding single justification for a metal spraying machine which we have in our plant.

J. G. MAGRATH: I know of very few dust fumes that are healthful. I will answer your question in this way. There is danger in spraying lead and cadmium, and a pressure ventilated helmet should be provided. Every part of the body should be covered preferably with rubber clothing, as the fumes will work in through ordinary cloth and into the skin. In the case of zinc the operator should be supplied with protective clothing and a respirator. It is always a good precaution to use a respirator where dust fumes are present.

I believe that even those who are interested in the promotion and sale of the equipment will agree with me. All dusts are injurious to a greater or lesser extent, and the dusts from metals that are sprayed to the greatest extent. The dust from black metals, i.e. monel, nichrome, steel and iron are not nearly as injurious as bronze and copper, and as we go from the black through the red and into the white series, they become increasingly dangerous as we proceed into the very low-melt point metals.

Insofar as protection from sand blasting dust is concerned, here occurs most of the objections that we have found to metal spraying. (Of course, at the present time, we are directly interested only in the promotion of the process in that it uses oxygen and acetylene—our gas products. We are not interested in the sale of the equipment). Many users of the metal spraying process are resorting to the rough threading process, of rough finishing the shaft rather than sand blasting.

W. A. SMILEY: As Mr. Walz pointed out, for some six months or more we have been spraying journals, particularly of electric motors, both the d-c. and a-c. type, and we have observed that the coefficient of friction between the customary bearing metal and the shaft was very considerably reduced on a sprayed metal coated shaft. The present undertaking was more of an experiment than anything else. We welded one end of it as was customary. The job was a Bethlehem gas engine piston about 22 ft. long and 15 in. in diameter. We laid on about 165 thousandths inch of metal which is probably a pretty heavy coating of metal. The idea is to place this in service and compare the service of the 1.20 carbon sprayed steel, on which I imagine Mr. Magrath will probably be able to tell you the exact figure which I imagine will be about 100 points carbon in the final condition, to compare that with the life of the original shaft which is from 8 to 9 years in service and also compare it against welded metal placed on the same shaft and working under identical conditions.

We realize that we are pretty near the economic limit of spraying. We are adding a lot of metal—about 200 lb. on one object and we are adding it on a large diameter. We are adding it thick. We are allowing $\frac{1}{32}$ in. to grind, .093 in. wear, and about .040 in. base. If this sprayed steel lasts as long as stories might lead one to believe, I may not live to be able to give you the report on this test.

E. P. O'NEILL: Where a shaft has been turned too low for a shrink or press fit of an inner race of a roller bearing, would it be possible to use metal spray, and if so, what would be the amount of metal over and above the standard shaft size to allow for a compression of this porous metal?

E. P. BURNS: It does not require the minimum thickness that would be required if it is to be used as a journal. In the case of building up for a press or shrink fit for the inner race of a bearing, it is best practice to hold the minimum thickness about .020 in. on the side. In an application like that there is no limit as to the size that is practicable, but at no time is it suitable to build up a race surface, that is, the wearing surface of the race where the rollers or balls run. There you have a stretching action that tends to break the bond of the coating.

J. H. BERRYMAN: In attempting to answer Mr. O'Neill's question I might cite an example that we are running into all the time at Sparrows Point. We have seven flying shears operating at the cold strip mill and it has become a continuous job in the past month to rebuild the journal for a press fit by metal spraying. We put a .90 carbon steel on there and we hold to a minimum of .0020 in. on that spraying. We have even gone so far in the last week as to go directly opposite to what Mr. Magrath spoke of this evening in spraying an eccentric wear. We had a shaft that was worn about .006 in. under on one side. We didn't go into this, however, as you might say sticking our necks out too far, but we did a test piece first, ground it, examined it, hit it, tried it out as best we could under normal conditions. We then applied the metal on our journal and we have to wait now to see actually what happens.

On that same job, on the opposite side of half the housing, it is out around .006 in. on each side, and to apply steel to that surface and attempt to bring that back to a true round would have been quite an item. We took the most apparent course and sprayed that surface with tin which was very easily scraped in, brought back to its original diameter and thus far has given us an excellent job.

Now, so much for the journals and that type of work. I would just like to bring up two other points. We found it very economical in our shops to use our operator of the metal spraying equipment to also do the grit blasting. We find that it is very profitable to have that man do both jobs and to know the complete operation. As a last point I might warn the men contemplating putting in this equipment that it will probably take them six to eight months to get the shop to use the equipment and then the next six to eight months in trying to keep the shop from going too far on it.

W. A. SMILEY: I would like to contribute just another word in connection with the question one of the gentlemen here has raised with regard to the use of anti-friction bearings over sprayed coatings. The thing that I wish to mention is that it is our standard practice on a large number of mill motors, where there is an impact on the bearing and where a sleeve bearing will not stand up in service, to take that motor, build up the shaft with 1.20 carbon steel after suitable preparation, to standard tolerances and shrink with hot oil shrink, a long-shaft-sleeve roller bearing onto the shaft and put it into the motor. We have not had a failure so far.

L. F. COFFIN: One of the most important fields for the use of the metal spray gun is in the building up of worn surfaces on complicated parts that cannot be welded, on account of distortion or affecting heat treatment. The building up of worn surfaces under inner races that have turned or that are undersize for other reasons, illustrates this application. In some cases the tightness of roller bearing inner race fits can be increased so as to counteract the effects of wear within the roller bearing races and rollers, as the increased diameter in the inner race tends to accomplish this. This latter particular use of the metal spray process has been applied to eliminating lost motion in roller bearings on main drums of flying shears that cut tin plate.

We have found spraying of lead on steel or cast iron surfaces is quite effective in resisting erosion especially in pipes or pumps but that its resistance to corrosion especially in salt water, is not as much as could be desired.

W. J. REA: I just want to say that it is not only our standard practice to recondition shafts for the inner race of the roller bearing but we have also successfully reconditioned the housings, and in at least one case, the fit of the outer race. This is particularly desirable in some of our operations where we are running high speed saw mandrels and we are very particular that there will be no welding done on them. They are expensive pieces to replace and metal spraying has been the answer to our difficulty there.

I would like to ask Mr. Magrath what is the maximum desirable thickness that you build up on a worn bearing?

J. G. MAGRATH: I do not think that there is any thickness limitation on building up on worn journals, other than economical. However, I do believe that it is not practicable, on flat surfaces, to build up much greater at any time than $\frac{1}{8}$ in. and seldom do we go above $\frac{1}{16}$ in. or $\frac{1}{32}$ in., because of the tendency of the metal to contract away from the base at the ends. On cylindrical shapes this danger does not exist.

In comment on Mr. Coffin's mention of lead, we seldom recommend lead for protection against atmospheric conditions or for resistance to water. We generally recommend aluminum or zinc. Lead is generally applied where we have exposure to industrialized atmospheres.

In commenting upon Mr. Berryman's experience in the spraying of eccentric wear on a cylinder surface, I had in mind a condition where the sprayed area would be allowed to taper off to nothing. We have, where it has been worn slightly on one side, provided a shoulder to work against, processed the surface and then sprayed.

E. P. BURNS: I would like to go a little further on Mr. Rae's question of maximum thickness. Usually the cost factor is the determining factor in such cases because the rate of deposition of metal spraying is considerably lower than by welding and if it is a case of building up over a quarter of an inch or more, it is better to weld, building up to within $\frac{1}{16}$ in. on a side and finish the build-up with sprayed metal. You will get a much better wearing surface than with the weld. The other thing is that you are not adding to the tensile strength of the shaft when you metal spray it and if it is worn too far undersize to have sufficient strength you should make the first part of the build-up by welding.

I cannot overstress the three things that cause most failures, any one or a combination of any of the three will do that. First: It is absolutely necessary to have a chemically clean and properly roughened surface and the roughness must be a torn surface that is easily obtained by a fine pitch rough torn thread or on flat or irregular surfaces by grit blasting with a course sharp cutting abrasive. Second: You must observe a minimum thickness of coating. You can build up for 10 or 15 thousandths and finish it up very nicely, which in some cases is all right for a press or shrink fit but never as a journal no matter what size the shaft is. The minimum for a journal is .030 in. on a side. Third: Avoid overheating. Mr. Magrath said that and I can't overstress the importance of not overheating. Someone mentioned one particular job where he did encounter failure due to the fact that they had a heavy build-up and the operator, in an effort to build the metal up as quickly as possible, did elevate the temperature too high. Don't get it too hot. You will find that a welder does not, in most instances, know when it is getting too hot because he is used to high heat, and if he doesn't see color on the shaft he doesn't think he is getting anywhere, and if he does with spraying he is not going to get anywhere. You should not allow the temperature of the surface being sprayed to exceed 250 degrees F.

Electric DIRECT RESISTANCE TREATING *of Wire*

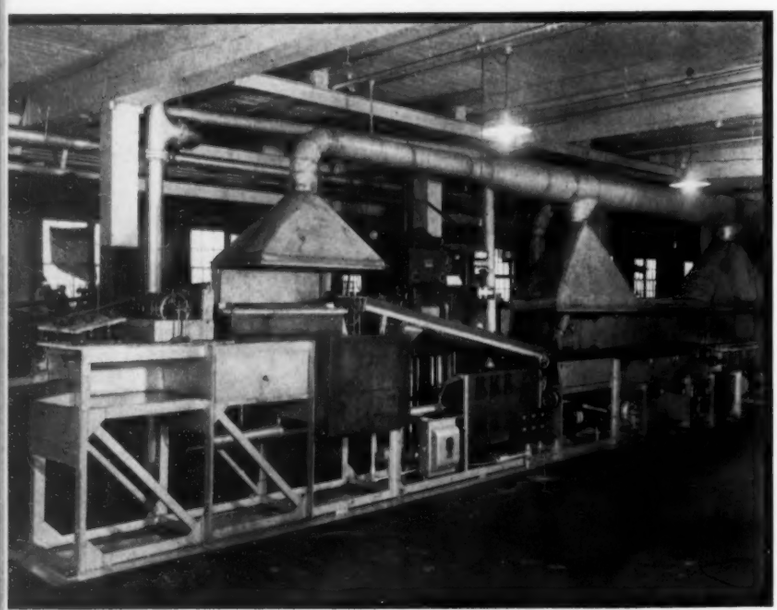
Presented before A. I. S. E.,
Cleveland District Section,
January 16, 1939

By J. W. MORRISON
Metallurgical Engineer
CLEVELAND WIRE SPRING CO.
CLEVELAND, OHIO

▲ ELECTRIC direct resistance heating, as applied to the patenting, tempering, and annealing of steel wire is an outstanding development in continuous heat treating operation. It makes possible more accurate control of heating and cooling cycles than heretofore possible in conventional practices, and the resulting product possesses superior and more uniform physical and fatigue properties, consistent with the demands of the wire users of today.

For some time, our company has been successfully using the electric direct resistance process for the continuous tempering of spring wire. This treatment is enabling them to fabricate a wire product of higher physical properties, greater fatigue strength, without surface decarburization and scale.

FIGURE 1—View of installation for continuous tempering of wire by electric direct resistance.



Conventional heat treating operations fail to produce wire with the highest physical properties possible, or to consistently insure the optimum qualities in a given steel. In this usual process where a furnace or lead bath is used to heat the wire, the heat is transferred to the wire from the outside inward, and before the interior has attained the temperature desired for quenching, the outside will have reached such a temperature, or even higher for an appreciable length of time. This results in an undesirable grain growth near the surface and a nonuniformity in grain size through the cross section. Under such heating conditions it is not possible to quench the wire the instant it has attained the desired degree of heat throughout its section, inasmuch as the temperature will have dropped before entering the quenching media, on account of the space separating the furnace or heating bath from the quench. In conventional practices, expediency in heating demands the use of a heating medium operating at a higher temperature than that actually required to heat the wire to the temperature desired. Therefore, the exterior of the wire is hotter than the interior at the moment the application of heat ceases. Moreover, as the wire is transferred from the heating furnace to the quench bath, it loses heat from its outer surface, and the temperature is not uniform throughout the cross section at the instant of quenching. In the case of furnace heating, refractories and their maintenance become a real problem, since the furnace temperatures used break down these refractories very rapidly. In lead pot heating, a considerable amount of lead is lost through oxidation, and maintenance costs are high due to the rapid deterioration of the pots. In either furnace or lead heating, considerable time is required to bring the furnace or pot to the work-

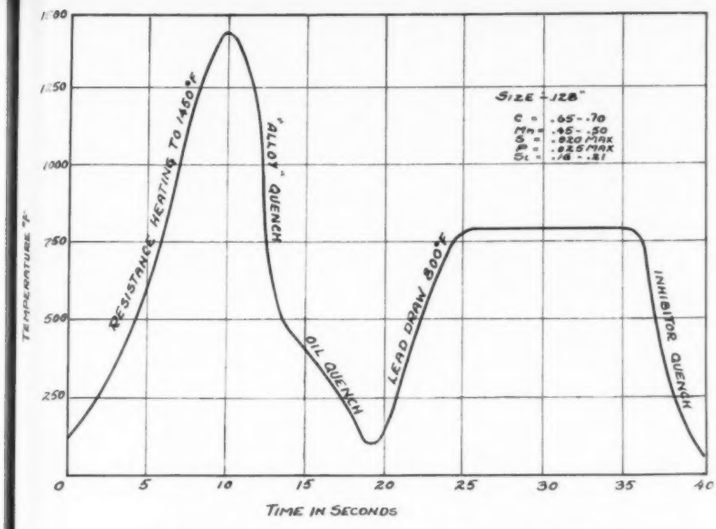


FIGURE 2—Time-temperature curve, showing the heating and cooling cycles for tempering by the electric method.

ing temperature. With such methods, the heating rate is more or less fixed, and the speed at which the wire travels to the takeups is rather slow, often only a few feet per minute.

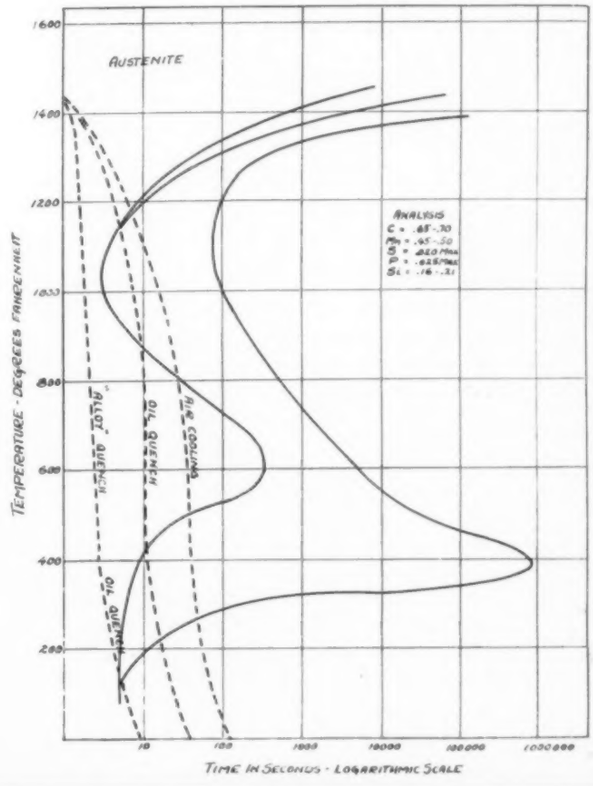
In electric direct resistance treatment, instead of heating the wire to the quenching temperature by means of passing it through a furnace or high temperature lead bath, an electric current is applied directly to the wire, and the wire attains the correct quenching temperature by virtue of its own electrical resistance. The heating is uniform throughout the cross section, and a much faster heating rate is possible. The heating and cooling rates are very flexible and can be easily adapted to any condition necessary to obtain a desired result. Extremely accurate control of both heating and cooling cycles is possible, and the quenching temperature of the wire can be controlled within a range of plus or minus ten degrees F. by controlling the power being applied to the moving strand of wire. The wire attains the quenching temperature in a few seconds, because the heating rate is not dependent on the thermal conductivity of the wire, furnace or pot temperatures, and other external influences, and far greater wire speeds than those used in ordinary procedures are possible. Quenching is accomplished on a rising temperature, that is, the temperature of the wire is increasing right up to the point where it enters the quench. This permits a much more rapid quenching to the temperature at which the desired transformation is to take place. The wire heating cycle is very efficient, all of the electrical energy being used to heat the wire.

Figure 1 shows the wire tempering installation at the Cleveland Wire Spring Company. In the foreground are the takeup reels on to which the finished wire is drawn. This unit is designed for tempering six strands of wire simultaneously, and will handle the size range from No. 11 gauge to No. 22 gauge, with a production capacity of about 600 pounds per hour. A tempering unit such as this can be converted into a patenting or annealing unit in about two hours time. No difficulties are encountered in reaching the high quenching temperatures necessary for the annealing of stainless and other austenitic steels.

Figure 2 graphically illustrates the heating and cooling cycles on No. 10½ gauge 0.128 in. diameter spring wire, tempered by the electric method. The wire is heated to 1450 degrees F. by means of passing an electric current through it. At this point it is quenched in a low-melting point alloy bath, maintained at 450 degrees F., and subsequently quenched in an oil bath where the transformation to the fully hardened product takes place. The wire then enters an electrically heated lead bath, the temperature of which is automatically controlled at about 800 degrees F., where it is drawn back to a hardness of about C-45 Rockwell. On leaving this bath it is cooled to room temperature in a bath which contains a rustproofing oil.

Figure 3 compares the speed of quenching in air, oil, and the "alloy-oil" quench which is used in the electric tempering treatment. The fine austenitic grain produced by the uniform and rapid rate of electric resistance heating requires a more rapid quench than can be obtained in the conventional oil quench. Quenching into a low melting point alloy bath down to 450 degrees F., and subsequently quenching in oil, fixes the fine

FIGURE 3—Curves showing comparative quenching speeds in air, oil, and alloy-oil, in relation to the "S-curve."



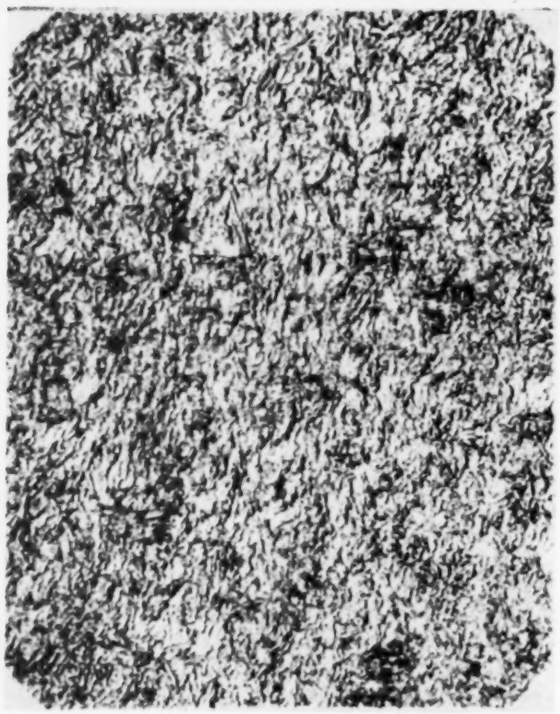


FIGURE 4—Illustrating the form of martensite produced by direct resistance heating and quenching in an alloy and on oil bath (x 2000).

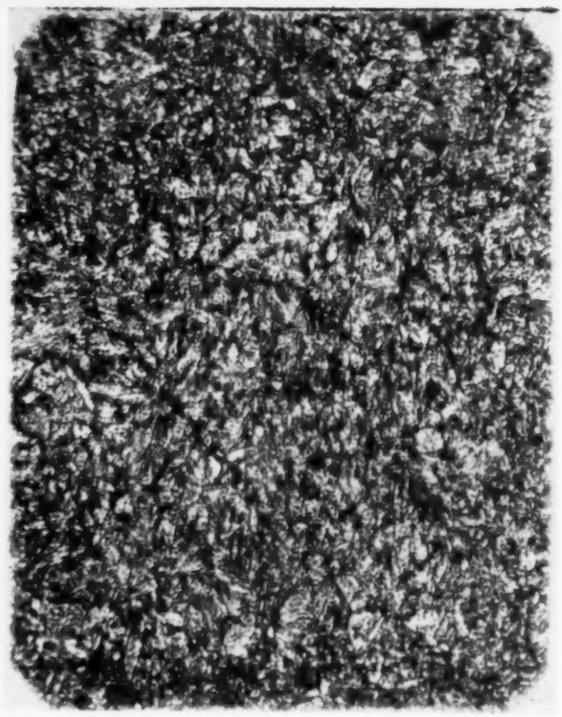


FIGURE 5—Showing the physical structure of wire which has been electrically tempered (x 2000).

grain produced by rapid heating, and insures a fully hardened structure. In this quenching arrangement, the physical stresses set up in the wire by the rapid quench to 450 degrees F., are relieved before the martensite transformation takes place in the oil.

Figure 4 at 2000 diameters magnification illustrates the form of martensite produced by electric resistance heating and subsequent quenching in an alloy bath and oil. The structure differs from the conventional form of martensite in that it possesses an extremely fine grain and there is an absence of any acicular, needle-like pattern. Although this structure is file hard (about C-65 Rockwell) it is extremely tough. The fully hardened structure produced electrically has greater toughness than the same wire conventionally treated.

The photomicrograph, Figure 5, at 2000 diameters, shows the physical structure of wire which has been electrically tempered. This is a straight 0.67 carbon steel spring wire which has been electrically tempered to a hardness of C-45 Rockwell. The electrical treatment produces a much finer grain than that obtained in conventional tempering operations, and the treated wire possesses physical properties superior to those of the same wire tempered by the conventional methods.

Table I compares the physical properties of carbon steel wire electrically tempered with those of the same wire conventionally tempered. As can readily be seen, the electrically treated wire possesses considerably higher physical properties than the regular oil tempered wire drawn to the same hardness.

In Figure 6, the photograph shows the unusually large reduction in area of a specimen of electrically tempered spring wire which has been subjected to a tensile test. Note the interlacing, cup type fracture.

Fatigue tests were conducted, to compare the endurance properties of electrically treated wires with the same wire, conventionally treated. The machine used for these tests was of the reversed flexure, constant strain type. It is capable of speeds up to 15,000 rpm. and is fitted with a vernier attachment for reading the angle of flexure to compute the stress applied to the wire.

Results of numerous fatigue tests proved conclusively that electrically tempered and patented wires possessed better endurance qualities than the same wires conventionally treated. The curves shown were determined by running a series of tests at different stresses. The tests were begun with an applied bending stress of over 90,000 pounds per square inch, and the stress was gradually reduced until the electric specimen ran 10,000,000 cycles without breaking. The endurance limits of the electrically treated wires were consistently higher than those of the conventionally treated wires, Figure 7. At an applied stress of 79,000 pounds per square inch, the oil tempered wire broke in 259,000 cycles, while the electrically tempered wire ran indefinitely. It may be noted that the fatigue limit of the electrically tempered wire was about 3000 pounds per

TABLE I

Comparison of Physical Properties of Tempered Wire.

	Wire Size	Johnson's Elastic Limit	Yield Point .2%	Tensile Strength P.S.I.	Per Cent Elongation in 2 In.	Per Cent Reduction in Area	Rockwell "C"
Electrically tempered.....	.128"	214,000	222,000	234,000	9.0	60.0	45–47
Oil tempered.....	.128"	175,000	186,500	218,000	9.0	53.0	45–47

	Per Cent Carbon	Per Cent Manganese	Per Cent Sulphur	Per Cent Phosphorus	Per Cent Silicon
Analysis:	.65–.70	.45–.50	.020 Max.	.025 Max.	.16–.21

square inch higher than that of the oil tempered wire.

On the average, two or three hundred springs are used in the construction of every automobile. These include coil springs, flat springs, and wire forms. Although the spring may seem to be a small, inconspicuous part of the unit on which it is used, yet the operation is absolutely dependent on it. The spring is the life, the controller, of the mechanism. Correct heat treatment puts life into the wire to be fabricated into springs and is responsible, to a large extent, for the service and fatigue life of the spring.

Electric direct resistance heat treating apparatus is extremely flexible. A tempering or patenting unit may be used for the annealing of stainless and other austenitic steels.

Figure 8, at 1000 diameters magnification, shows the

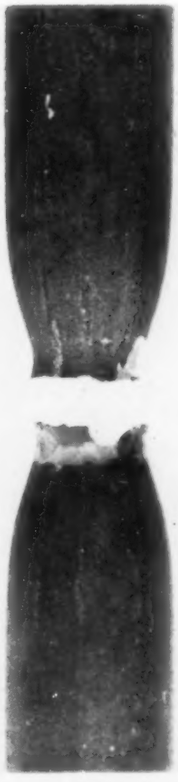
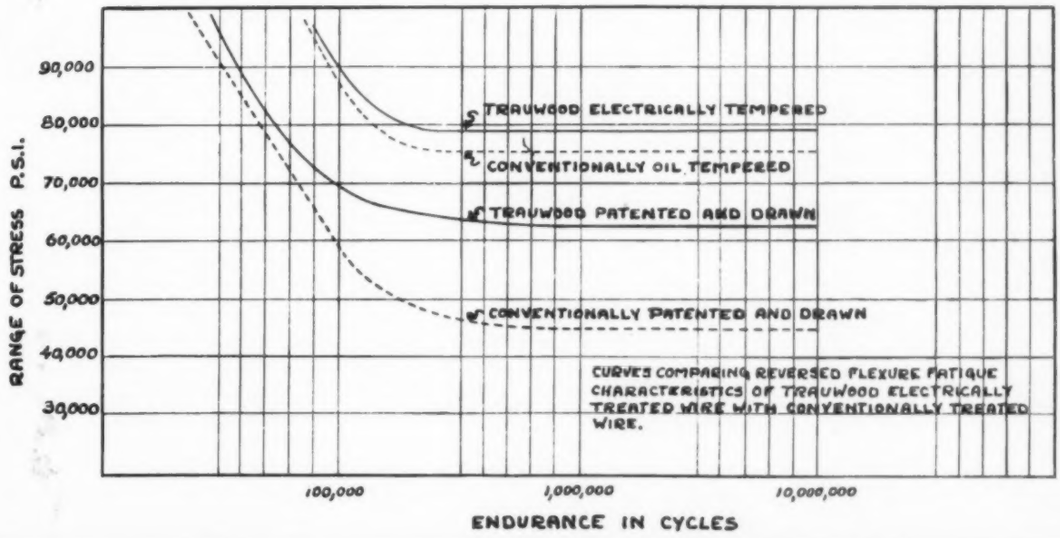


FIGURE 6—Electrically tempered spring wire shows a large reduction of area and an interlacing cup-type tensile fracture. (Left)

FIGURE 7—Curves comparing reversed flexure fatigue characteristics of conventionally treated and electrically treated wire. (Below)



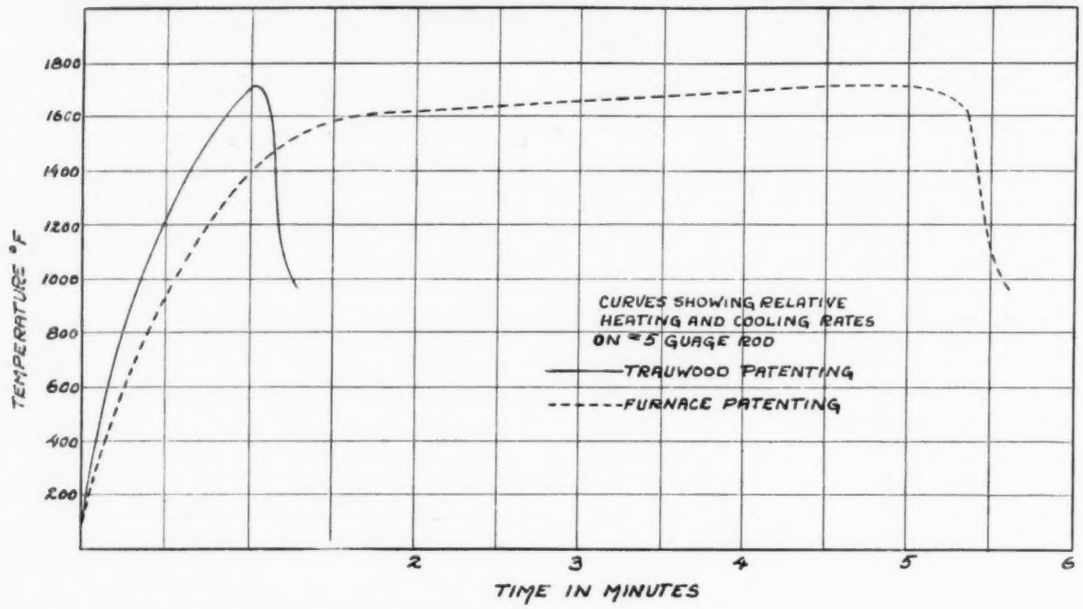


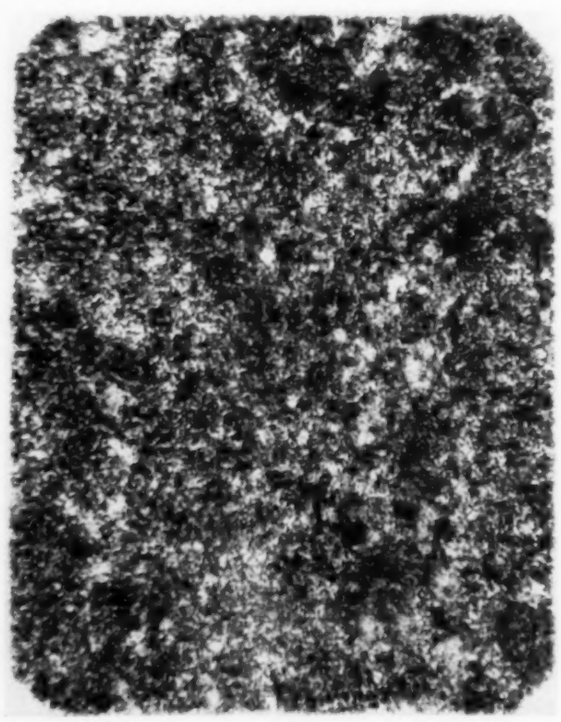
FIGURE 9—Curves showing relative heating and cooling rates on No. 5 rod patented by the conventional method and by the electric method.

structure of an 18-8 stainless steel which was annealed electrically. The wire was heated by the direct resistance method to 2100 degrees F., and rapidly quenched on a rising temperature, to obtain the best physical properties for drawing to smaller sizes. After this treatment it was found possible to accelerate the speed of drawing, and also to make larger reductions in drafting.

An electric tempering installation can also be used for

FIGURE 8—Photomicrograph showing structure of electrically annealed stainless steel.

FIGURE 10—Photomicrograph showing structure of spring wire which has been patented electrically (x 2000).



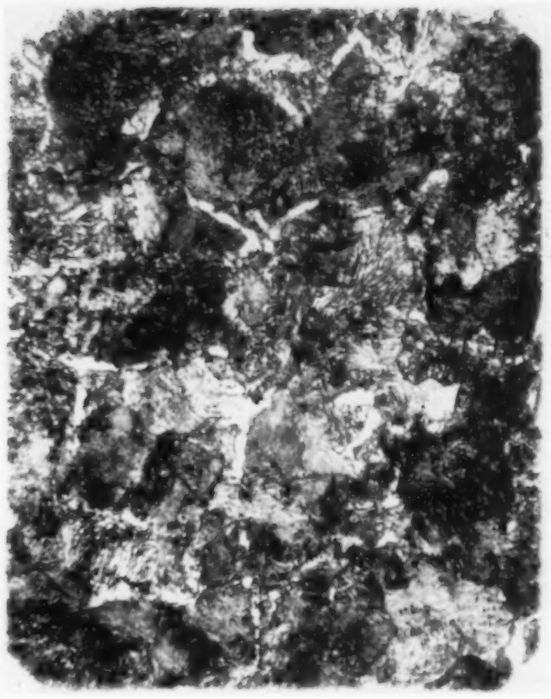


FIGURE 11—Photomicrograph showing structure of spring wire conventionally double lead patented (x 2000).

FIGURE 12—Photomicrograph of spring wire conventionally patented by furnace heating and salt quenching (x 2000).

the patenting of wire. The conversion from tempering to patenting can be made in about two hours time.

Curves, comparing the relative heating and cooling rates on No. 5 hot rolled rod, patented by the regular furnace method, and by the electric method, are shown in Figure 9. As can be seen from an examination of this curve, a much more rapid heating rate is possible with electric resistance heating than with furnace heating. This rapid rate of heating produces an extremely fine austenitic grain, and a good dispersion of the carbides in the patented structure. Another important point in the electric patenting treatment is the fact that there is no soaking period in the heating cycle. As soon as the wire attains the quenching temperature, it enters the lead or salt quench. The soaking period is not necessary in resistance heating, because the rapidity and uniformity of the heating accelerates the changes of solution and carbon diffusion which takes place at the maximum quenching temperature. In the patenting of wire by this method, a finely dispersed sorbitic structure

TABLE II

Comparison of Physical Properties of Patented Wire.

	Wire Size	Johnson's Elastic Limit	Yield Point .5%	Tensile Strength P.S.I.	Per Cent Elongation in 2 In.	Per Cent Reduction in Area	Rockwell "C"
Electrically patented	.128″	121,000	128,000	164,000	11.0	62.0	35–38
Conventionally furnace patented	.128″	65,000	89,000	146,000	9.5	29.2	31–34

	Per Cent Carbon	Per Cent Manganese	Per Cent Phosphorus	Per Cent Sulphur	Per Cent Silicon
Analysis:	.67	.75	.016	.024	.17

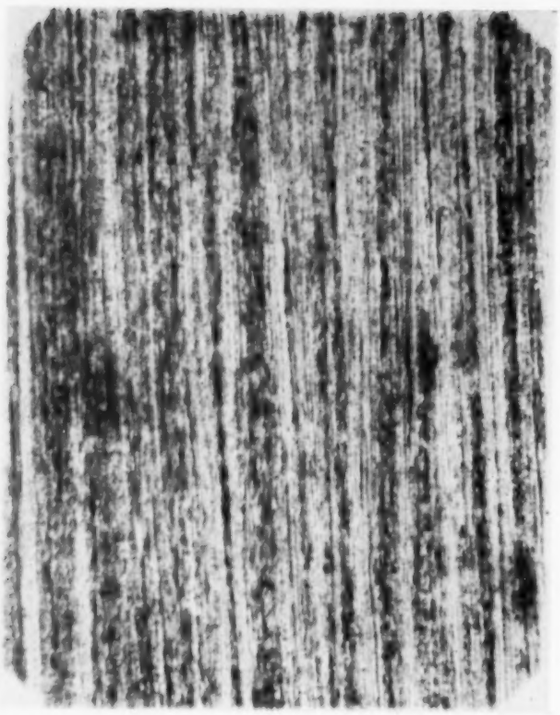
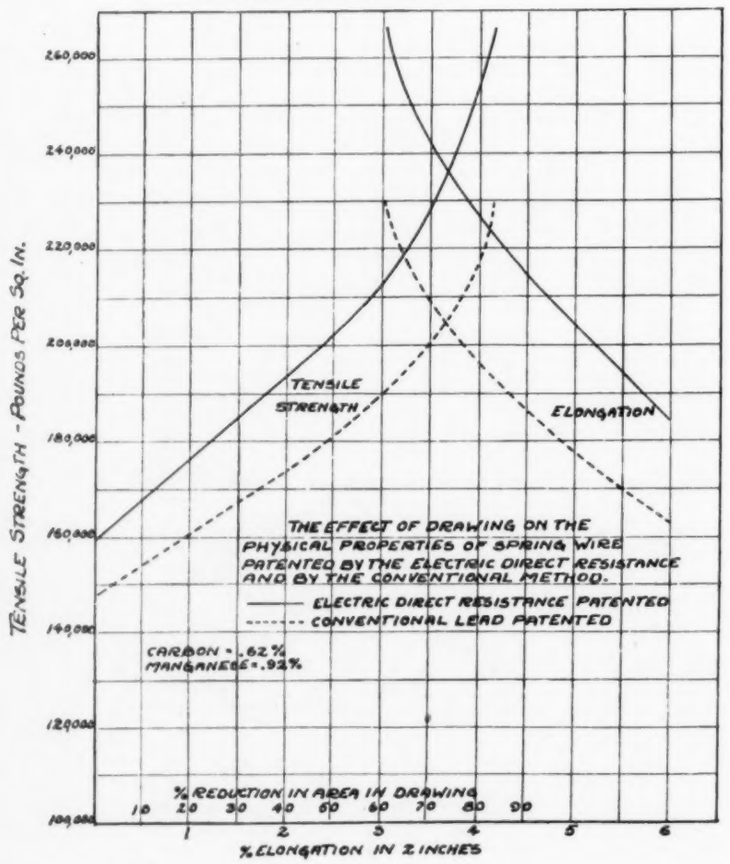


FIGURE 13—Photomicrograph showing typical structure of electrically patented and drawn wire.

FIGURE 14—Curves showing effect of drawing on the physical properties of electrically patented and conventionally patented wires.



can be produced without the use of temperatures quite as high as those used in conventional methods. Any temperature desired can be attained quickly and easily, and any temperature changes necessary during operation can be affected very rapidly. Wire patented by the electric method has an ideal structure for the subsequent operation of drawing.

The photomicrograph, Figure 10, at 2000 diameters shows the structure of spring wire which has been patented electrically. The wire was heated by electric resistance at 1500 degrees F., and quenched on a rising temperature into a lead bath maintained at about 975 degrees F. Note the uniform dispersion of the carbides throughout the structure.

The photomicrograph, Figure 11, also at 2000 diameters magnification, shows the structure of the same wire conventionally double lead patented, that is, heated to the quenching temperature in a high temperature lead pot, and subsequently quenched in another lead bath maintained at about 975 degrees F.

The photomicrograph shown in Figure 12 at 2000 diameters magnification is a sample of spring wire conventionally patented by furnace heating and salt quenching. As can readily be seen, the structure is a good deal coarser than that of the electrically treated wire.

There is a considerable difference between the physical properties of wire electrically patented and the same wire conventionally patented.

From Table II it is very evident that the electrically patented wire possesses superior physical properties. An interesting point in this connection is the fact that, although the electrically treated wire is somewhat harder, it is more ductile, from the standpoint of its reaction to cold flow in drafting. The ductility desired in the patented state is not in the sense of ease in drawing, but rather, the greatest capacity for uniform cold flow.

Wire drawn from electrically patented stock has a short fibre, as compared to the wire drawn from conventionally treated stock.

The photomicrograph, Figure 13, at 2000 diameters magnification, is typical of electrically patented and drawn structures. This particular wire was drawn from a No. 13 gauge electrically patented wire to No. 27 gauge. This represents about a 97 per cent reduction in drawing.

Wire drawn from electrically treated stock possesses considerably higher physical and fatigue values than those of conventionally patented and drawn wires.

Curves, comparing the effect of drawing on the tensile strength and elongation of electrically and conventionally patented wires, are shown in Figure 14. From this curve it is evident that a higher tensile and a better elongation in a given reduction can be obtained from the electrically patented wire. In practical application, this means that one or two holes in drawing can be eliminated to obtain a desired tensile strength.

Reversed flexure fatigue tests made on wires drawn from stock patented by the two different methods disclosed the fact that the short fibered wire drawn from electrically patented stock possessed considerably better endurance properties. Not only was its endurance at

TABLE III

Comparison of Fatigue Properties of Wires Drawn from Stock Patented by the Electric Direct Resistance Method and by the Conventional Furnace Method

Alternate Bending Stress in Lb. per Sq. In.	Endurance—Number of Reversals Required for Fracture	
	Drawn from Stock Patented by Electric Direct Resist. Method	Drawn from Stock Patented by Conventional Furnace Method
110,000	19,000	14,400
105,000	22,400	17,400
100,000	26,000	21,000
95,000	31,000	25,500
90,000	37,000	31,000
85,000	46,000	37,000
80,000	57,000	45,000
75,000	74,000	55,000
70,000	107,000	67,000
65,000	225,000	80,000
60,000	INDEFINITE	100,000

stresses above its fatigue limit better than that of the conventionally treated and drawn wire, but its fatigue limit was considerably higher than that of the wire conventionally treated and drawn, Figure 7.

Table III shows the relative endurance properties of wires drawn from electrically treated stock and conventionally treated stock.

In general, on the strength of numerous physical and fatigue tests made on wires drawn from electrically patented stock, it may be said that the range of limits of physical and fatigue values is narrower in the case of the electrically treated material, when compared to wires given identical drawing treatment from conventionally patented stock.

A very important feature of the electrical treatment is the fact that there is no surface decarburization and, although no special atmospheres are used in the heating cycle, there is practically no scale, as compared to conventionally treated wires. The photomicrograph shown in Figure 15 illustrates the surface decarburization usually found in conventionally furnace-patented wires. During the necessary "soaking period" in the heating cycle, in the case of furnace heating, the carbon content of the surface of the wire is depleted through oxidation. The resulting product has a lower carbon exterior as shown.

Figure 16 illustrates the surface condition of conventionally patented wires. The oxide scale, as you will notice, has a patch appearance, some of the scale having fallen off before the wire reached the takeups.

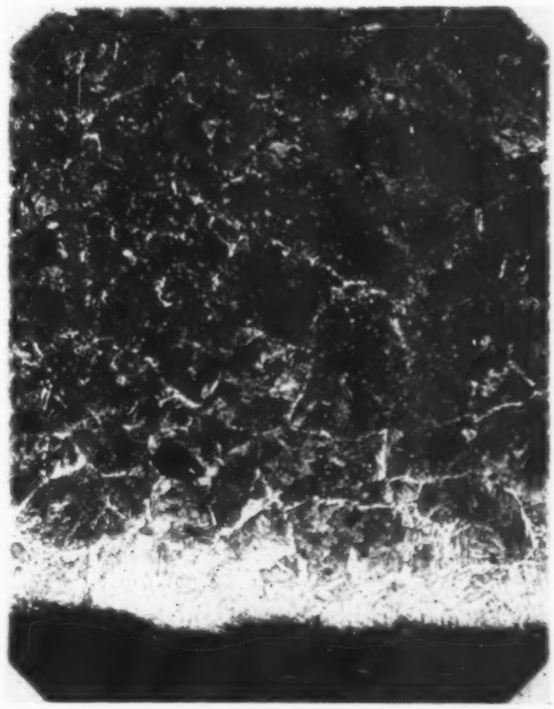
The surface condition of electrically patented wires is shown in Figure 17. Because of the rapid rate of heating, and the short period of time at which the wire is at the scaling temperature, only a light, continuous, oxide film is present on the surface of the wire. Only about two thirds of the pickling time given to conventionally treated wire is necessary to remove the film on electrically patented wire. After pickling and drawing, the electrically treated wire has superior surface qualities.

Electric direct resistance patenting equipment is so designed that continuous pickling, coating, and baking equipment may be used in conjunction with it.

The keystone section used in coiling lock washer shapes is usually rolled from spheroidized stock. The spheroidizing treatment is usually a batch operation, carried out in salt pots. Considerable difficulty is encountered in these salt bath spheroidizing operations, and non-uniformity is often found in the treated product. Experiments conducted have shown that wire continuously treated by electric direct resistance possessed a structure which was very adaptable to the rolling of keystone section, and the subsequent operation of lock washer coiling. The lock washers coiled from the electrically treated stock possessed a high degree of uniformity.

Electric direct resistance continuous patenting, tempering, and annealing equipment is fully automatic in its operation. Once a unit is started on production, it

FIGURE 15—Photograph showing surface decarburization usual in conventional furnace patented wire (x 2000).



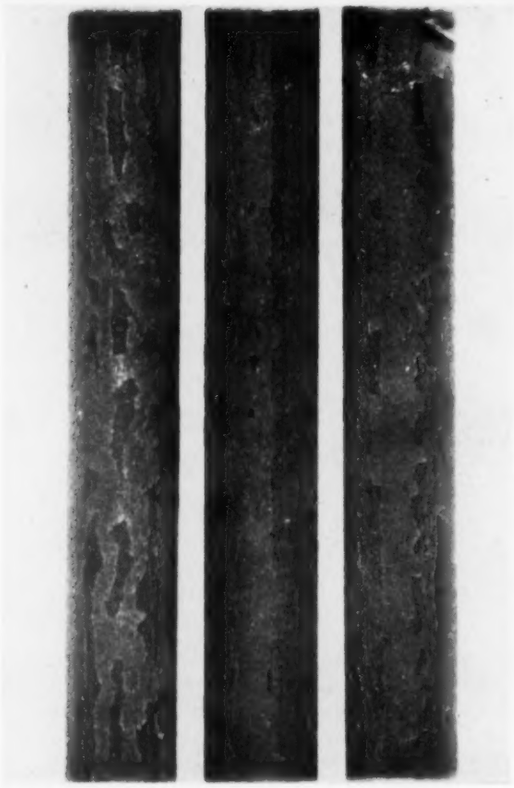


FIGURE 16—Illustrating the surface condition of conventionally patented wire.

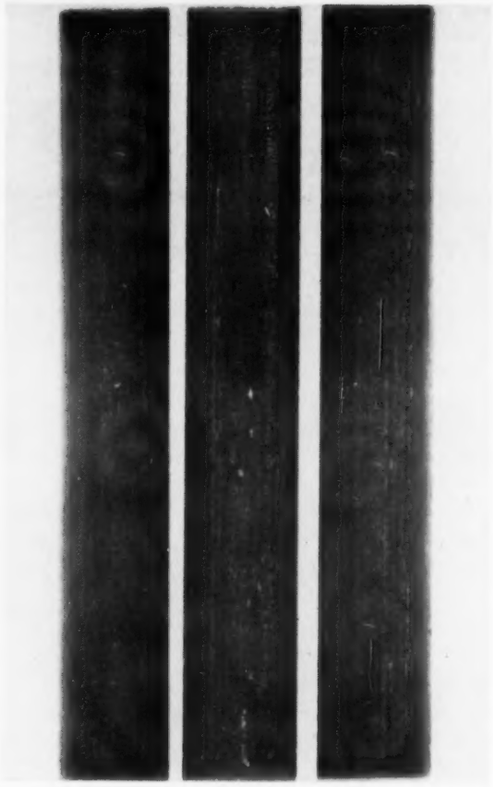


FIGURE 17—Illustrating the surface condition of electrically patented wire.

requires no further attention other than loading the payoff reels and handling the wire on the takeups.

An electric wire treating installation can be brought up to working temperature in about one and one-half to two hours time from cold, after which time production can begin. The temperature of the wire is controlled automatically, and can be raised or lowered quickly and accurately.

The cost of treatment by the electric direct resistance method is relatively low. The power required to heat the wire to the quenching temperature is between 160 and 200 kwh. per ton of wire treated. As mentioned before, the thermal efficiency of the heating cycle is high, over ninety per cent. All of the electrical power is used to heat the wire, there being only slight radiation and other losses. Maintenance costs on the equipment are low in comparison to furnace and lead heating operations. The maintenance costs on furnaces and high temperature lead pots amount to a considerable figure.

The operating labor costs on electric wire treating equipment are relatively low. One man may operate the tempering installation, taking care of the payoff reels and the takeup reels. The operation of an electric wire treating unit is essentially a wire handling proposition.

Further advantages of this method of treatment, many of which are obviously apparent, may be summarized as follows:

1. A product with higher and more uniform physical and fatigue properties, and greater impact strength is obtained.
2. There is no surface decarburization, and there is practically no scale, even on wire run without the use of special atmospheres in the heating cycle. The treated wire has an excellent surface condition.
3. Greater wire speeds than those used in conventional practices are possible.
4. A much finer grained structure can be produced than possible with conventional practices.
5. The heating and cooling cycles can be controlled very accurately.
6. The wire is quenched on a rising temperature, and exactly at the desired temperature, instead of on a temperature which is falling, as in the usual heating practices.
7. A wire tempering unit can be converted into a patenting or annealing unit in about two hours time.
8. In patenting, where continuous cleaning equipment is used, there is an elimination of a great deal of handling time to and from pickling vats, cooling operations, baking ovens, etc., as all these operations are done in a continuous process.

DEVELOPMENTS *in* *Electro-Tinplating of* STRIP STEEL

BY D. C. BAKEWELL, *Vice President*

BLAW-KNOX COMPANY

PITTSBURGH, PENNA.

Presented before

A. I. S. E. Birmingham Section,

April 24, 1939

▲ FOR the last three-quarters of a century, the basic principles of electro-plating have been well understood and commercially practiced; but it is only for the last twelve years that the continuous electro-plating of wide strip has been developed. J. S. Nachtman supervised, in 1927, the installation of a continuous unit for electro-galvanizing wide strip, which was probably the first installation of this kind in the world. After he had successfully operated this unit, he designed and installed similar units for the electro-plating of copper, tin, cadmium and nickel on steel strip.

There were many problems which had to be solved, such as the application of the plating current to the moving strip; the cleaning of the surface of the steel strip prior to plating; the guiding of the strip through the various tanks; means for evenly distributing the coating metal; and the accurate coordination of the moving strip with the plating current.

These problems were worked out so that a satisfactory product was produced very soon, with the exception of the tin strip. The main difficulties here were that the coating of tin was too soft for satisfactory drawing operations, and that the product had a dull matte finish instead of the ordinary bright tin surface. To overcome this last difficulty, the rotary type brushing machines were used to improve the lustre.

It was found that this scratch brushing increased the porosity, caused a substantial loss of tin (the coating of electro tinplate is approximately .00005 in. thick), in some places removing all the tin from the surface, and did not harden the coating for later drawing operations. This early work on scratch brushing has been recently verified by the International Tin Research and Development Council in a bulletin by Messrs. D. J. MacNaughton, W. H. Tait and S. Baier, which says:

> "Preliminary tests indicated that precipitated chalk and Vienna lime were the most promising materials for polishing the soft and exceedingly thin tin coatings. It was found, however, that effective polishing involved a loss of from 10-13 per cent of the weight of coatings, 0.0001 inch in thickness in the case of smooth matte deposits, 18-20 per cent in the case of the rough matte deposits, and about 7 per cent in the case of the semi-bright deposits. In view of these considerable losses, trials were subsequently carried out to determine the effect of scratch-brushing using the same apparatus. It was found that in the case of smooth matte coatings, the losses were lower than those produced by polishing, to a degree dependent upon the nature of the wire of the scratch brush, i.e., 6-8 per cent with nickel-silver wire, 2-2.5 per cent with steel wire, and only 0.5 per cent with brass wire. The scratch-brushing treatment in all cases produced a fairly uniform and semi-lustrous surface.
>
> "The porosity of the tin coatings before and after polishing and scratch-brushing respectively was determined in a number of cases using the hot-water test. These tests were confined to smooth matte deposits. It was found that polishing which produced a 12 per cent loss in weight of this type of coating doubled the porosity of the coating. Scratch-brushing with the steel wire brush which produced a much lower loss, viz:, 2.5 per cent, caused a similar increase in porosity, while in the case of the nickel-silver wire brush, which produced a 7 per cent weight loss, the porosity of the coating was quadrupled. It thus appears that scratch-brushing has a greater effect in exposing the basic metal than is produced by polishing, for an equal loss in weight. In the case of the specimens that had been scratch-brushed with brass wire, however, associated with the very low percentage weight loss, the increase in porosity was only slight."*

There have been several methods tried and developed, after finding scratch brushing was not completely satisfactory. The method which seems to produce the most desirable results is passing the electro-tinned strip through a hot oil bath at a high enough temperature to melt the tin, and then following this by a quick quenching in cold oil. Two plants are now operating in the United States on this system commercially, and there

*"Technical Publications of the International Tin Research and Development Council"—Series A, Number 52; Page 19, Paragraph 3.

is one using scratch brushing on a product which does not require a very bright surface.

Attempts have been made, here and abroad, to use an alkaline tin bath, but the present American practice is to use acid bath which has three very definite advantages over the alkaline bath:

1. No heating is required for the bath.
2. A lower voltage may be used.
3. Most important, the speed of deposition of tin on the strip is more than double for the same cathode current density.

Both soluble and insoluble anodes have been used, but with the proper electrolyte the soluble anode gives a very much higher recovery of tin and is, therefore, the logical commercial method. The electrolyte is, of course, one of the most important factors in satisfactory electro-tinplating. The desirable characteristics of the electrolyte are that:

1. No sludge should be formed upon continuous operation due to the oxidation of the stannous salts to stannic forms.
2. It can operate efficiently at current densities up to 300 amperes per square foot.
3. There should be no polarization or passivity of the anodes during operation.
4. The bath should operate at practically 100 per cent anodic and cathodic efficiency even at high current densities.

The eventual use of electro-tinplating in place of the present hot dip method seems to be inevitable. With as little tin on the strip as .9 lb. tin per base box, the electrolytic tinplate shows better quality at a lower cost. The best known test of tinplate is the hydrogen evolution test. With .9 lb. tin per base box, electrolytic tinplate gives higher hours when tested than hot dipped tinplate with 1.5 lb. tin per base box, or even slightly more. In other tests, such as those for porosity, electrolytic plate is definitely better with equal weights of coating.

The tin coating on electrolytic is much more uniform — there are no "drip edges". The electro-deposited surface is 100 per cent pure. This is important as the corrosion of tinplate in service is dependent on the electrolytic action set up by the impurities in the tin and the acid or alkaline medium of the food product.

Menders are eliminated with their costly redipping. In the electrolytic process, a special oil is used, one which is not easily oxidized by heat, and, therefore, does not tarnish or stain the surface.

The greatest advantage is, of course, the reduced amount of tin necessary to obtain equivalent results, which reduces the cost of the plate. A feature which is also lost sight of is that an inventory reduction of at least 33⅓ per cent is possible, and, with the normal price of tin, this is a large item. The speculative feature of the tin market is reduced by just the same amount. In addition to the saving in cost of tin, it is believed the continuous system of electro-tinplating, which I will briefly describe, will give an additional substantial reduction in the production costs of manufacturing tinplate.

The recommended method is to take strip in coils from the temper mill, which are automatically conveyed to either of two payout reels. The strip steel then passes through an automatic seam welder, which is followed by a slack producer, which must be arranged to allow time for the welding operation. The strip is then passed through a special cleaning bath, which thoroughly cleans the strip, and puts a blue oxide coating on the strip.

In the next operation, the steel passes through a pickling bath, which removes the oxide produced in the cleaning bath. This leaves the surface of the steel chemically clean, and this is vitally important in the production of good electro-tinplate.

After passing through rotating scrubbers, and being thoroughly washed, the strip passes into the plating tank where the strip receives a fine-grained deposit of pure metallic tin evenly distributed over the surface. When the steel leaves the plating tank, it is thoroughly washed and dried, then passed through an oil bath and heated to a temperature below the melting point of tin, then into a second oil bath which raises the temperature above the melting point of tin, into another cold oil bath to quickly solidify the tin before crystal growth can be formed.

The steel then passes through a solvent cleaner, is washed and dried, run through a flattening and cutting machine, and then to the classifier.

The tinplate can be produced by this method with from less than ¼ lb. per base box to 2 or 3 lbs. per base box, or more, and can be varied easily to suit the customers' requirements. It is very bright, freer from porosity, and can be soldered as easily as hot dipped tinplate.

It is different from scratch brushed electrolytic tinplate as the melting operation produces a thin layer of tin-iron alloy between the tin and the base metal, which improves the drawing qualities materially, besides closing the minute pores to a large extent.

Research has been carried on and electrolytic tinplate produced with an undercoating of pure iron and nickel-iron alloys. Very little tin is required for the outer coating, and this product is practically free from porosity.

The development of electrolytic tinplating has been slow because of natural caution of tinplate producers, and because of the large investments already made in hot dipped tin mill equipment, But, with the possibility of an acute shortage of tin in case of war, with the improved quality possible at lower costs, the rapid development of the manufacture of electrolytic tinplate seems assured.

DISCUSSION

PRESENTED BY

P. J. BOWRON, Assistant Superintendent, Annealing Department, Tennessee Coal, Iron and Railroad Company, Tin Mill, Fairfield, Alabama.

J. S. NACHTMAN, Manager, Electrochemical Processes Division of Blaw-Knox Company, Pittsburgh, Pennsylvania.

W. H. MANDY, Lubrication Engineer, Texas Company, Birmingham, Alabama.

J. E. HARRELL, Chief Electrician, Tennessee Coal, Iron and Railroad Company, Fairfield, Alabama.

R. E. STURDY, Assistant Superintendent, Tennessee Coal, Iron and Railroad Company, Sheet Mills, Fairfield, Alabama.

W. W. GARRETT, JR., Director of Electrical Laboratory, Tennessee Coal, Iron and Railroad Company, Birmingham, Alabama.

F. M. STURGESS, Master Mechanic and Chief Electrician, Tennessee Coal, Iron and Railroad Company, Wire Works, Fairfield, Alabama.

D. C. BAKEWELL, Vice-President, Blaw-Knox Company, Pittsburgh, Pennsylvania.

J. R. CUMMINGS, Electrical Foreman, Cold Reduction Department, Tennessee Coal, Iron and Railroad Company, Birmingham, Alabama.

J. C. CANNON, Assistant Superintendent, Cold Reduction, Tennessee Coal, Iron and Railroad Company, Tin Mill, Fairfield, Alabama.

B. E. MELTON, Assistant Superintendent, Maintenance, Tennessee Coal, Iron and Railroad Company, Tin Mill, Fairfield, Alabama.

H. C. RODGERS, Superintendent, Tin House, Tennessee Coal, Iron and Railroad Company, Birmingham, Alabama.

R. L. DOWELL, Electrical Turn Foreman, Tennessee Coal, Iron and Railroad Company, Birmingham, Alabama.

NELSON M. JENKINS, Assistant Superintendent, Tin House, Tennessee Coal, Iron and Railroad Company, Birmingham, Alabama.

C. E. ALLEN, Master Mechanic, Woodward Iron Company, Woodward, Alabama.

P. J. BOWRON: I would like to ask a question. Mr. Bakewell referred to one of the first steps in cleaning the steel, and said that in cleaning it he produced a blue oxide. Is it necessary to do that?

J. S. NACHTMAN: I would say it is necessary, to get best results. When a steel strip is broken down in a mill and then annealed, it may have a bright and clean appearance, but as a matter of fact there are oxides and other impurities on the surface and when this annealed strip is temper rolled these surface oxides and impurities are rolled into the surface of the strip, forming what might be called a film on the strip. This film is not uniform. When an oxide is formed on the strip and then dissolved off in a pickling bath, the surface of the strip is clean.

P. J. BOWRON: As I understand it, Mr. Nachtman, you simply pickle off whatever oxide happens to be on there rather than deliberately put on any additional oxide?

J. S. NACHTMAN: We do deliberately put on oxide on the strip in addition to the oxide rolled in during the temper rolling. This additional oxide is integral with the original oxide and impurities, and gives the strip a blue color. When this blue oxide is removed by pickling, the original oxides and impurities are taken off with it.

P. J. BOWRON: You don't feel that you could pickle it properly unless you put your blue oxide on it?

J. S. NACHTMAN: No, I don't say that. By using the blue oxide cleaning treatment we get less porosity in our tinplate than is obtainable when pickling alone is used. Also, a smoother deposit of tin is obtainable. It is not necessary to be so careful in guarding against rolling in impurities during the temper rolling of the annealed strip if the blue oxide cleaning is subsequently applied. We believe our blue oxide cleaning is the least expensive way of preparing the strip for reception of the tin coating.

P. J. BOWRON: Is that blue oxide on there similar to steam blue?

J. S. NACHTMAN: Yes, it is the same as steam blue except that the oxide layer is not as thick as the steam blue.

P. J. BOWRON: Do you pass it through a hot oil bath and let the atmosphere hit it?

J. S. NACHTMAN: No. The strip is passed through a hot alkali electrolytic bath as anode to form the blue oxide. Different types of oxides may be obtained on the strip varying in color and composition by varying the combination of the solution and current densities.

P. J. BOWRON: Is that a patented process?

J. S. NACHTMAN: We have patent applications pending for it, but I do not know if they will be granted.

MEMBER: That nine-tenths pound per base box, what is that in feet per minute?

J. S. NACHTMAN: Nine-tenths pound of tin per base box of tinplate is obtainable at a tinning line speed of about 225 feet per minute. That is the speed at which our line will operate to make tinplate which we believe to be suitable for wet pack cans.

W. H. MANDY: This oil bath,—what is the type of oil you are using? You refer to it as a mineral oil, but what is the viscosity of the oil, and what are some of its other qualities?

J. S. NACHTMAN: It is an ordinary engine oil with flash point of about 650 degrees F.

W. H. MANDY: You are not speaking of an ordinary engine oil with a flash point like that? (*over*)

J. S. NACHTMAN: It is a Pennsylvania type. The cost of the oil is very low—approximately sixteen cents per gallon. It is cheaper than palm oil.

W. H. MANDY: You spoke of the oxidation of palm oil. Is that due to the heat?

J. S. NACHTMAN: Palm oil is capable of oxidizing rapidly at high temperatures. As you probably know, any vegetable oil decomposes faster than mineral oil.

W. H. MANDY: I understand that the reason for using palm oil is that it doesn't leave a residue which they claim mineral oil does.

J. S. NACHTMAN: I do not think that is the case. I believe any vegetable oil will give more residue than mineral oil.

J. E. HARRELL: This speed of 225 feet per minute —what does the current density on the anode show?

J. S. NACHTMAN: The current density on the anode is approximately 80 amperes per square foot of surface.

J. E. HARRELL: How long would your strip be in the plating bath?

J. S. NACHTMAN: Approximately four to five seconds.

R. E. STURDY: Is it necessary to assort this product?

J. S. NACHTMAN: We think it will not be necessary to assort the product. When we started working on steel strip furnished by the different steel companies, we found that there is quite a wide difference in the steel produced by the steel companies due to the difference in temper rolling and annealing practice. In order to get a uniform product from these various steel samples, we developed our blue oxide cleaning process. We believe we can make good tinplate from steel strip furnished by any of the steel companies.

R. E. STURDY: Another concern, I think, is working on another process—an electrolytic process. Is that any different from what you are working on?

J. S. NACHTMAN: I don't know whether they have a new process or not, but the processes I am familiar with are alkaline tinning processes. That is, they use an alkaline solution Our solution is acid. When compared with acid solution, the alkaline solution has a very low efficiency and the deposition of tin is only about one-half as fast. I would say that it would require three to four alkaline plating units to get out the same tonnage as one of our tinning units.

W. H. MANDY: Could this process be applied to coating terneplate?

J. S. NACHTMAN: Yes, we have a process for terneplating of strip wherein we control the percentage of tin and lead in the deposited coating. For instance, we can deposit 80 per cent lead, 20 per cent tin, or any other desired proportion of tin and lead.

We have processes for the plating of almost any metals on strip or wire, such as lead, copper, nickel, iron, etc., or alloys such as brass, bronze, alloys of iron, etc.

MEMBER: Do you make any attempt to protect the sheared edge of the finished plate from oxidation while in storage or in transit to the can manufacturer?

J. S. NACHTMAN: No; we have done some work in regard to edges but we find that if the strip is kept dry it will store better than if oil is put on the edges.

W. W. GARRETT: I want to know the current and voltage you use and the capacity of the generator.

J. S. NACHTMAN: It depends on the width of the strip you are plating, how fast the strip is traveling, and the thickness of the coating being plated. We must know the exact operating conditions to answer your question.

W. W. GARRETT: What amperage do you use?

J. S. NACHTMAN: We use up to 300 amperes per square foot of strip surface, depending on the thickness of the coating required.

F. M. STURGESS: Would the voltage be different for the different thicknesses of plates, or would it depend only on the electrolyte you are using?

J. S. NACHTMAN: If the electrolyte is the same, the voltage will be approximately constant for constant current regardless of strip thickness.

F. M. STURGESS: About how much is that?

J. S. NACHTMAN: For most of our baths, under normal conditions the voltage is approximately four volts.

F. M. STURGESS: Do you have any trouble with the generators?

J. S. NACHTMAN: We have experienced very little trouble with our generators.

P. J. BOWRON: How do you pass this strip from the hot oil bath above the melting point of tin to the oil bath below the melting point? Does it go through the air?

J. S. NACHTMAN: No, the strip passes from the hot oil to the cold oil without passing through the air and without being contacted by anything except the hot and cold oil while in the molten condition.

W. W. GARRETT: One of your samples you passed around is very bright, and the other is not so bright. What causes that difference?

J. S. NACHTMAN: The bright samples have been passed through the hot and cold oil baths and the tin coating has been fused to the strip. The bright samples are suitable for the canning of foods, etc. The semi-bright sample has not been fused in the hot oil but is just as it comes from the plating bath. The semi-bright sample is for dry pack, etc.

W. W. GARRETT: About what coating do you have on those sheets?

J. S. NACHTMAN: On the semi-bright pieces you have seen there is approximately one-half pound tin per base box. On the bright samples there are different

thicknesses of coating; the coating range is from one-half to one pound tin per base box.

W. W. GARRETT: Is that the equivalent of the hot dip?

J. S. NACHTMAN: The reports we have received from several companies show that our bright tinplate with nine-tenths pound tin per base box is equivalent to one and one-half pound per base box from the hot dip process. The average hydrogen evolution tests on our tinplate with nine-tenths pound per base box is 56 to 58 hours.

MEMBER: Are any troubles encountered in soldering tinplate from the electrolytic process?

J. S. NACHTMAN: You will have trouble with soldering electrolytic tinplate if the base metal is not properly prepared. It is also important to have all the plating solution removed from the electrolytic tinplate, otherwise the solution left on the strip will oxidize and give trouble soldering.

In our process we prepare the base stock properly and obtain a finished tinplate which is absolutely free from stannic tin. No one testing samples of our tinplate has complained about difficulty in soldering.

D. C. BAKEWELL: I might say that one of the large can companies states our plate solders very satisfactorily. They run it through their regular lines.

F. M. STURGESS: Are there any figures to show what per cent of the tinplate sold is made by the electrolytic process?

J. S. NACHTMAN: No, I haven't the figures. Of course, you know the Gary plant is running five days a week and twenty-four hours a day. I understand the Crucible Steel Company at Midland, Pennsylvania, is making shipments of the electrolytic tin.

F. M. STURGESS: Those are the two plants making it?

J. S. NACHTMAN: The Thomas Steel Company in Warren, Ohio, is also making electrolytic tin. They use a hot oil bath to fuse the coating.

W. H. MANDY: Is there any residue left in the tank containing the electrolytes at all similar to the dross in the present box?

J. S. NACHTMAN: It depends entirely upon the nature of the electrolyte. Our electrolyte is a fluoride bath and does not give a residue. A sulphate bath as is used in some of the plants in this country does give a residue which is called "sludge". It is not similar to the dross in the hot tin, but will represent a loss of tin unless the sludge is refined to recover the tin.

W. H. MANDY: Do you have to use a flux?

J. S. NACHTMAN: No. It is only necessary to clean the strip properly before it is tinned.

J. R. CUMMINGS: Does the tin remain in the solution itself and make the solution stronger?

J. S. NACHTMAN: No. If the proper electrolyte is used the tin deposited on the strip is taken from the solution at the same rate that the tin is dissolved from the anodes so that a constant tin content is maintained in the solution.

J. C. CANNON: I see one of those samples is very smooth; another has a kind of orange peel surface on it. Does that come from the original surface of the strip, or from not enough polishing?

J. S. NACHTMAN: We do not polish our tinplate at all. The orange peel surface is partly due to the surface of the steel strip and partly due to the fact that these samples were made at the laboratory. In the laboratory the samples were dipped in a hot oil bath and then transferred to the cold oil through the air, whereas in commercial installations the strip is transferred from the hot oil to the cold oil without being exposed to the air.

W. H. MANDY: Does it make any difference whether the change from the temperature of the hot oil to the cold oil is gradual or must there be a sharp contrast?

J. S. NACHTMAN: In order to get the smoothest plate the temperature change should be quite sharp.

W. H. MANDY: Why couldn't you use the same oil tank and keep your hot oil on top with low specific gravity, and let it go from the top down through the bottom and out?

J. S. NACHTMAN: That is exactly what we are doing.

We have learned a great many things about oil during our research work. When we started this process we had to use a combination of mineral oil and vegetable oil in order to get an oil bath which would fuse the tinplate properly. Finally we have worked out a mineral oil which is satisfactory. Palm oil has very definite disadvantages. It breaks down rapidly under high temperatures, it is expensive, and it must be bought outside of this country.

MEMBER: How is that oil temperature controlled?

J. S. NACHTMAN: The temperature is controlled automatically by thermostats.

MEMBER: The oil flows up?

J. S. NACHTMAN: Each zone in the oil tank is equipped with an external circulation system including a heat exchanger for maintaining the oil temperature at the desired value.

J. R. CUMMINGS: Do you have to control that electrolyte? What means do you have of keeping that conductivity of the electrolyte the same? I guess it does have to be the same.

J. S. NACHTMAN: The electrolyte is controlled through analysis just like you have to in a pickling process. However, the analysis is not critical and can vary over quite a wide range.

J. R. CUMMINGS: How long is the electrolyte tank?

J. S. NACHTMAN: In a line capable of producing

tinplate with nine-tenths pound tin per base box, at 225 feet per minute, the tank is about 15 feet long.

B. E. MELTON: Do you have one generator for each tank or one generator supplying more than one tank?

J. S. NACHTMAN: We use two generators for the plating tank; one generator for each side of the strip. We also have a generator for the blue oxide cleaner.

J. R. CUMMINGS: What is the capacity of those generators?

J. S. NACHTMAN: 30,000 amperes.

J. R. CUMMINGS: About 150 kilowatts?

J. S. NACHTMAN: That is right.

J. R. CUMMINGS: What voltage do you use?

J. S. NACHTMAN: From three to six volts.

P. J. BOWRON: I understand you actually have one of these large producing units working somewhere. You were speaking of laboratory samples.

J. S. NACHTMAN: These are laboratory samples, but the plant at Midland is producing—Thomas Steel is producing, and the plant at Gary is operating. I, myself, tinplated strip continuously up to 22 in. wide at Warren.

P. J. BOWRON: Do any of those plants incorporate all the features you have brought out in the paper?

J. S. NACHTMAN: No, this paper covers new and improved features. We have worked on the problems of electroplating tin for the past twelve years and have been able to simplify it considerably. The principles of electroplating have been fairly well understood for the past fifty years. I should say that our major improvement has been in the mechanical and electrical features. The guiding of the strip, and the control of tension in the strip are very important items in successful electroplating.

H. C. RODGERS: In this terneplating, do you put the tin on first, or the lead?

J. S. NACHTMAN: We have two different terneplating processes. In one we plate lead on the steel strip and then plate tin upon the lead. The thus plated coating is then fused to the base metal. In the second process we plate an alloy of lead and tin from a single electrolyte. Both methods are satisfactory, depending upon the thickness of coating and what you want to use the product for.

H. C. RODGERS: You speak of nickel. How do they solder nickel?

J. S. NACHTMAN: It was quite a difficult proposition to solder nickel up until about two years ago. The International Nickel Company started research work on this problem sometime ago, and I heard through the research department about two years ago that they were successful in the soldering of nickel.

H. C. RODGERS: Is that the iron-nickel, or the nickel?

J. S. NACHTMAN: If you can solder nickel you can solder iron-nickel. It is much harder to solder nickel.

R. E. STURDY: Has the hot process any advantage over this process? Do you feel in the course of time there will be any hot process?

J. S. NACHTMAN: I believe that the hot dip tinning process will eventually be replaced by the electroplating process. I will make a general statement about electroplating.

When it is desired to obtain a light coating on strip or wire the electroplating process is superior, but when it is desired to have heavy deposits there are several features which would have to be considered in comparing the hot dip process with the electroplating process. If it is desired to have a product which will stand deep drawing, the electroplated coatings will be more desirable as they will stand deeper drawing operations than a product produced by the hot coating method. The electroplating process may be a trifle more expensive for the production of heavy coatings but the product will be superior as far as drawing and forming are concerned. Also, the coating will be more uniform and have less porosity.

R. L. DOWELL: You mentioned in the paper it would take very close synchronization of the speed of various units. I would like to know how much complication this is going to make in your control, and this winding at low tension you have mentioned.

J. S. NACHTMAN: Our control system is somewhat similar to that which is used on tandem rolling mills. The tension is automatically controlled.

R. L. DOWELL: As I understood it you can't use the high tension that you ordinarily use in coiling strip.

J. S. NACHTMAN: You should not. The tension should be kept very low to avoid distortion of the strip. We do this through the use of a variable voltage system for driving all of the rolls in the line by individual motors. If the tinplated strip becomes distorted it is practically impossible to make it flat again.

P. J. BOWRON: Reference was made to electrogalvanizing. Is anybody making wide strip electrogalvanized?

J. S. NACHTMAN: As I said before—the electrogalvanizing has some features superior to hot-galvanizing. The heavy electro-galvanized coatings may be more expensive, but they are definitely superior.

P. J. BOWRON: Is anybody doing it?

J. S. NACHTMAN: Yes, one of your competitors is installing a line now for electroplating with heavy deposit. We are laying out a plant for one of the large steel companies, to electro-galvanize strip up to 48 in. wide, and to put on one and one-half ounce of zinc per square foot of strip surface. Of course, we have not sold this yet.

J. E. HARRELL: Is that a continuous process?

J. S. NACHTMAN: Yes, it is a continuous process. We do not recommend plating sheets.

J. E. HARRELL: Is the position of your anode important?

J. S. NACHTMAN: I wouldn't say that it is critical. The heavier the coat the more critical it is going to be.

J. E. HARRELL: Then, as your anode wears out, do you have any method of controlling that distance?

J. S. NACHTMAN: The anodes should wear out uniformly if the contacts to the anodes are properly made and if the current is properly distributed. The anodes should be kept the right distance from the strip, but the change in distance, due to the wearing away of the anodes, makes very little difference.

N. M. JENKINS: Is the electrolyte temperature maintained within a fixed range?

J. S. NACHTMAN: Within twenty or thirty degrees F. is satisfactory.

N. M. JENKINS: In your tank are the strips vertical or horizontal?

J. S. NACHTMAN: In most of our tanks the strips travel vertically, unless we want to operate at a very low speed.

C. E. ALLEN: What is the widest strip that is being done?

J. S. NACHTMAN: I think the widest strip that is being electroplated at the present time is about 32 in. However, there is no limit to the width of strip as far as the plating is concerned. You could plate a strip up to 120 in. wide.

As I said before, the main problems in the electroplating of strip are mechanical and electrical.

PLAN TO ATTEND . . . . . .

A. I. S. E.

ANNUAL SPRING CONFERENCE

APRIL 1st and 2nd, 1940

TECHNICAL SESSIONS

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Inspection Trips to The ANDREWS STEEL COMPANY, and to the MIDDLETOWN and HAMILTON WORKS, AMERICAN ROLLING MILL COMPANY.

Gauge Control for COLD STRIP MILLS

By F. MOHLER

Industrial Department

GENERAL ELECTRIC COMPANY

SCHENECTADY, NEW YORK

Presented before the A. I. S. E.
35th Annual Convention,
Pittsburgh, Pa., Sept. 26-30, 1939

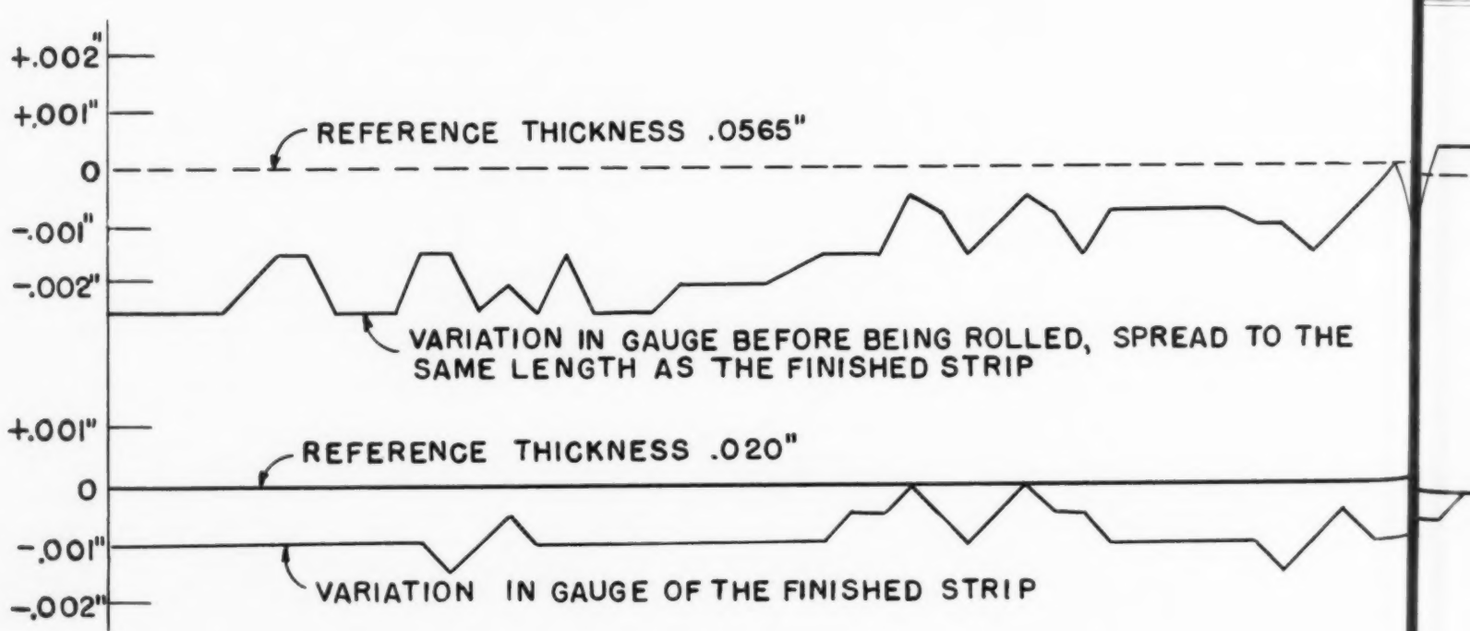
▲ THE gauge or strip thickness produced on a cold mill is becoming a problem of ever increasing importance. The tolerances or allowable variations in gauge are continually shrinking. The requirements are becoming more stringent. Accurate gauge has opened up new fields and widened the market. Without it, the maintenance on intricate dies would be prohibitive, and such processes as lithographing bottle tops before punching would be impossible. The ratio of "off" gauge to "on" gauge bears a direct relation to the cost of producing cold strip. It is not surprising, therefore, that a considerable interest has been aroused in gauge control.

Gauge control is a subject, not a gadget. It embraces all of the multitude of causes of gauge variation and how they can be controlled. The interrelation of these causes is complex, and not too much is known of their relative importance. The purpose of this paper is not to break down all of these causes and study them individually, but to deal with their combined effects and means for their control.

POSSIBLE CAUSES

In order to control gauge, it is necessary to know

FIGURE 1—Graph showing variations in gauge between entering and finished strip where no adjustments are made on the mill while rolling.



something of the possible causes for variation. The following is a partial list of these:

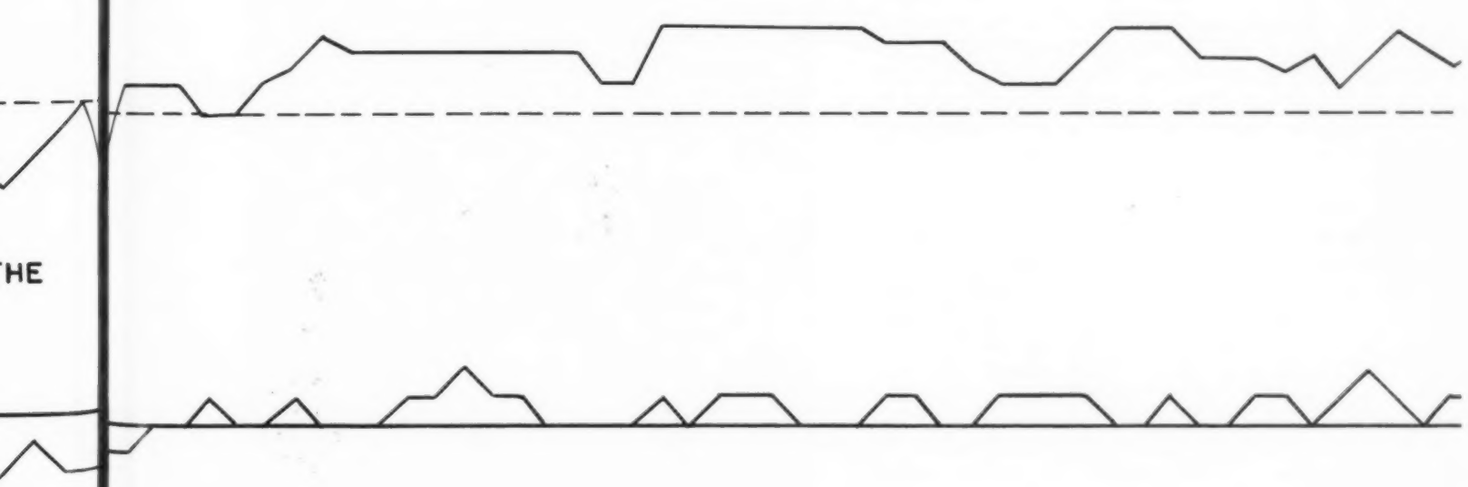
1. Mechanics of the mill:
   a. Housing stiffness
   b. Roll spring
   c. Roll shifting
   d. Bearing deflection
   e. Roll shape
   f. Relative hardness between working roll, backing up roll, and material to be rolled.
   g. Concentricity of rolls
   h. Screwdown gear ratio
2. Material entering mill:
   a. Variations in gauge
   b. Variations in width
   c. Variations in hardness
   d. Variations in analysis
   e. Edge cracking
   f. Inclusions
3. Mechanical operation of mill or rolling practice:
   a. "Leveling off" temperature of mill and relative temperatures of its component parts.
   b. Amount, temperature and point of application of cooling solution
   c. Amount, temperature, type, viscosity and point of application of lubricant.
   d. Roll contour
   e. Roll surface
   f. Temperature of strip
   g. Speed of rolling
4. Electrical operation of mill:
   a. Tension control
   b. Screwdown control

No doubt there are other possible causes, but that is a rather respectable list. Some of the foregoing may be negligible. The predominating, in all probability, are roll shape, cooling solution, lubrication, speed, variations in incoming strip, and tension.

Assuming that the mechanics of the mill are perfected to a practical limit, that the incoming strip is maintained uniform in all respects as far as humanly possible,

F. MOHLER

and that the rolling practice is flawless, can anything be done electrically to reduce the still remaining off gauge? Unquestionably yes, within certain limits. Do not be misled, however, that these "electrical cures" are "cure-alls" for poor rolling practices. From a broad viewpoint of good gauge the electrical cures are minor as compared to good rolling practice. Electrically, ten-



sion and the control of the screwdowns are the only weapons of attack upon gauge.

The combined effect of all the various causes of gauge variation is radically different during acceleration and deceleration, as compared to the steady rolling condition obtained at running speed. The subject of gauge control will therefore be discussed in two parts: The first, dealing with variations in gauge while at "running" speed, and the second, during acceleration and deceleration. Under each part the method of attack will be to discuss in order the combined effect, possible predominating causes, the inherent characteristics which should be obtained in the basic electric equipment, and lastly, the special control which can be utilized to make a further reduction in off gauge.

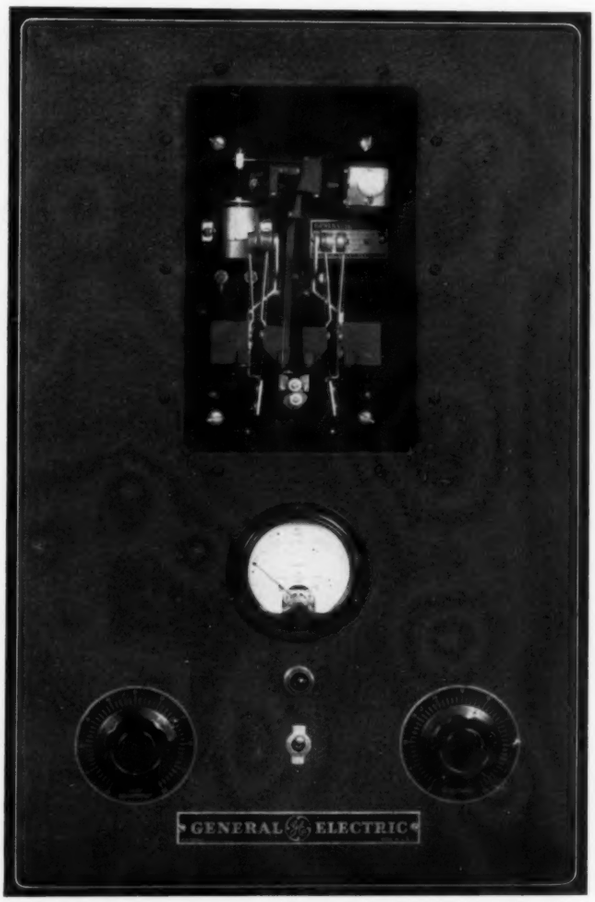
VARIATIONS IN GAUGE WHILE AT RUNNING SPEED

With a modern mill of good design and good rolling practice, it appears from observation and practical tests that the most predominating cause for variation in gauge is the variation in the incoming strip. In order to verify this, a strip was "miked" every three feet before it entered the mill. Then, after the mill had been set up properly and a number of strips of the same gauge had been rolled, this strip was entered into the mill. During the rolling of this strip, the screwdowns, speeds of each stand, tension between stands, cooling solution, lubrication, and so forth, were left strictly alone. After the strip was rolled, it was miked every five feet, and the results plotted—gauge versus length. The gauge for the incoming strip was also plotted and spread out so its ends came opposite those of the finished strip. This made it possible to compare the variation in incoming thickness to that of the finished at any point. A typical portion of these results is shown in Figure 1. It is impossible to show the entire length because of lack of space. It will be noted that when the entering gauge ran thin, the finished gauge also ran thin. Then when the entering gauge ran heavy, the finished gauge also ran heavy. Quantitatively, the variations in finished gauge are less than those entering, but it must be borne in mind that the strip was reduced. To give a true picture therefore, the variation in per cent should be used. Taking a corresponding portion of the entering and the finished thickness when both ran thin, it will be noted that the entering strip was approximately .0025 in. light from .0565 in. or 4.4 per cent and that the finished strip was .001 in. light from .020 in., or 5 per cent. On the heavy side the average appears to be off .0012 in. from .0565 in. or 2.1 per cent and off .00035 in. from .020 in. or 1.7 per cent. Even if allowance is made for possible errors in miking and plotting so that the portion entering is not exactly opposite the corresponding finished strip, it is very clearly seen that the variations in entering thickness are carried through the mill. In addition, it would appear that the per cent variation is of the same order of magnitude. Thus, it is believed that the predominating cause for off gauge while at running speed is the variation in the incoming strip.

The inherent characteristics of the electric drives which will best attack this variation in gauge is a study in itself that took several years to arrive at an answer. In order to solve such a problem it is first necessary to evolve a theory and then either prove or disprove it. If it is disproved, the very facts that led to its disproof will probably lead to the establishment of the correct theory. It was believed that there was a tendency for the strip to slow down between stands when the strip ran thick, and speed up when it ran thin.

This is not an obvious fact. Whether this happens or not depends upon the combined effect of the various causes for off gauge. For instance, if the first pair of rolls in a tandem mill spring slightly as the strip thickens, and the succeeding stands spring the same percentage, there is no change in strip speed. Variation in lubrication may have exactly the opposite effect. These may offset each other completely or partially. Again, if each succeeding stand springs a progressively greater percentage, the tendency would be for the strip to slow down. This seems a reasonable assumption, because the strip is more difficult to reduce in each succeeding stand. If this latter is true, and is the predominating factor, then the tension would increase between stands if constant relative roll speeds were maintained. This increase in tension should attack the heavy gauge, and at least tend to pull it on gauge. However, this increased tension, as well as the increased rolling load, would tend

FIGURE 2—Electrical control instrument for automatically controlling strip gauge by controlling tension between the last two stands.



to slow down the motor, depending upon its speed regulation, or in other words, its per cent drop in speed with an increase in load. The poorer the regulation, the greater would be the drop in speed, and therefore the less tendency to pull it on gauge.

In order to test the soundness of this theory, a mill was run under three different conditions: first, with regulators for maintaining constant current input to the various stand motors; second, with motors having 10 per cent compounding; and third, with straight shunt wound motors having a 2 per cent drop in speed from no load to full load. The current regulators can vary the speed of the motor through its entire speed range in order to hold constant current. Thus, on the same mill it can be said that it was run with motors having a speed regulation of: first, 50 per cent; second, 10 per cent; and third, 2 per cent.

Records were kept of the gauge rolled under each of these three set-ups. The mill was operated under the same conditions, on the same orders, and for periods of time long enough to make a reasonable and fair comparison. The results showed that the best gauge was obtained from the shunt motors, next best with the compound wound motors, and worst with constant current regulators.

Thus, it would appear beyond doubt that shunt wound motors and no regulators whatever have the best inherent characteristics for obtaining good gauge. However, any one of the three methods can be used with fair results, as will be evidenced by the following.

Once a mill is up to speed, the operator can readily control the gauge within very close limits, which are well within the allowable tolerance, by merely controlling the tension between the last two stands of a tandem mill, or the front and back tensions on a reversing mill. An occasional operation of the screws may be necessary, depending upon the uniformity of incoming strip, roll shape, cooling solution and lubricant. This is common practice in most modern mills, and the author has observed coil after coil pass through the mill with scarcely a flicker of the continuous gauge needle while at running speed.

This operation is possible whether current regulators are used with the motors, or compound wound motors, or straight shunt wound motors are used. The only control necessary is a hand operated vernier or fine adjusting rheostat in the current regulator or motor shunt field circuit, as the case may be.

However, the operator will have less juggling to keep on gauge with the shunt wound motors than with the compound motors or current regulated motors. Thus they not only have inherently the correct characteristics, but are simplest and are strongly recommended.

There is still another angle which should not be overlooked in connection with the basic motor control. Several years ago the mills were having considerable trouble with breakage between stands. Accordingly, there was considerable agitation in regard to constant tension control. It was obvious that no control of power input could be used because there was no way of differentiating between rolling load and tension load. Therefore, the tensiometer was developed to actually measure the tension in the strip and regulate the motors, so as to maintain constant tension in the strip between stands. In this case, when the strip tended to run thick, the tension remained constant and did nothing to pull it down to the proper gauge. On the other hand, when the strip tended to run thin, the tension was also maintained, but this tended to pull it down thinner. Of course, the fact that constant tension was maintained tended to reduce breakage, but at the sacrifice of gauge. The variation in gauge when this method is used is greater than any of the other three methods, and this scheme as a means for regulating the tension was quickly discarded.

It is readily seen therefore, that when the strip tends to inherently run thick, tension should be increased in order to maintain constant gauge, but this increase in tension, if carried too far, may cause breakage, especially on brittle strip or that with badly cracked edges. In striving for constant gauge therefore, the hazard of breaking is increased.

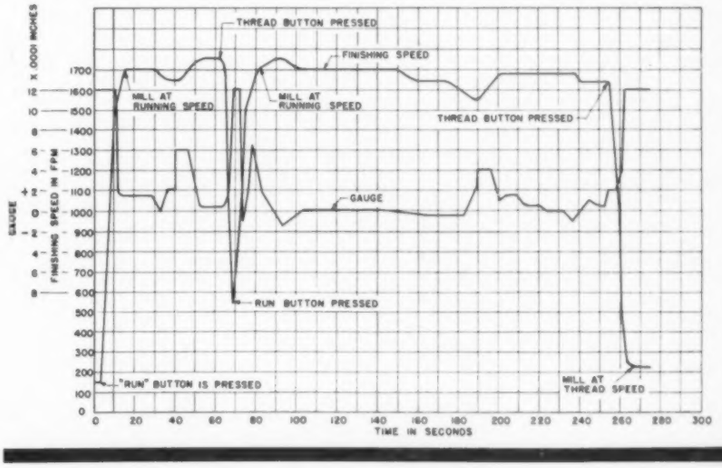
It is here that the tensiometer for indicating purposes only has its greatest value. The operator maintains gauge mainly by controlling the tension, and it is, therefore, vital that he know what tension he is getting. If the tension gets too great, he will run into breakage, and if the tension gets too low, pinching and roll spoilage will result. With a tension indicating instrument immediately beside the continuous gauge indicator, he can watch both simultaneously. With a mill rolling at 2000 ft. per min. or faster it is difficult to watch the gauge meter and at the same time judge the tension either by eye or by a stick.

Thus the inherent features of the electric equipment for assisting the operator in doing a good job of maintaining gauge while at running speed are simply straight shunt wound motors and indicating tensiometers.

Now, what special electric features can we use to further assist the operator?

Although the operator can control the gauge as described above, it is a tedious job, requiring constant attention. There is a tendency for him to take his eyes away from the meter because it is tiresome. Therefore, a means called "automatic gauge control" has been developed, which automatically increases the tension

FIGURE 3—Graphic representation of actual test, showing variations in strip gauge with speed through the mill.



between the last two stands when the gauge runs heavy, and decreases it for light strip. This is done by means of a motor-operated vernier rheostat in the field of the last stand motor, which speeds it up and slows it down respectively. The control is initiated from the continuous electrolimit gauge which indicates the thickness of the finished strip, and is in common use on cold strip mills.

The power output from such a gauge is so minute that it must be amplified many times in order to get enough power to control the motor-operated vernier rheostat. This is accomplished by a system of vacuum tube amplifiers. The amount the tension must be increased or decreased depends upon the amount the gauge is varying and the control is so arranged that the value of the increment adjustment of tension depends upon the amount of gauge variation. In addition, the variation in tension required to bring the strip on gauge for a definite variation in thickness, depends upon the type of steel being rolled. An adjustment is provided to take care of this. After an adjustment of tension is made, it requires a slight time for the motor to respond, and the strip which is rolled under the new condition must pass from the mill through the gauge before the results are known. This interval timing between increment adjustments of tension is also controlled automatically. If the first correction is not sufficient, additional increment adjustments are made at definite intervals of time until the strip is on gauge.

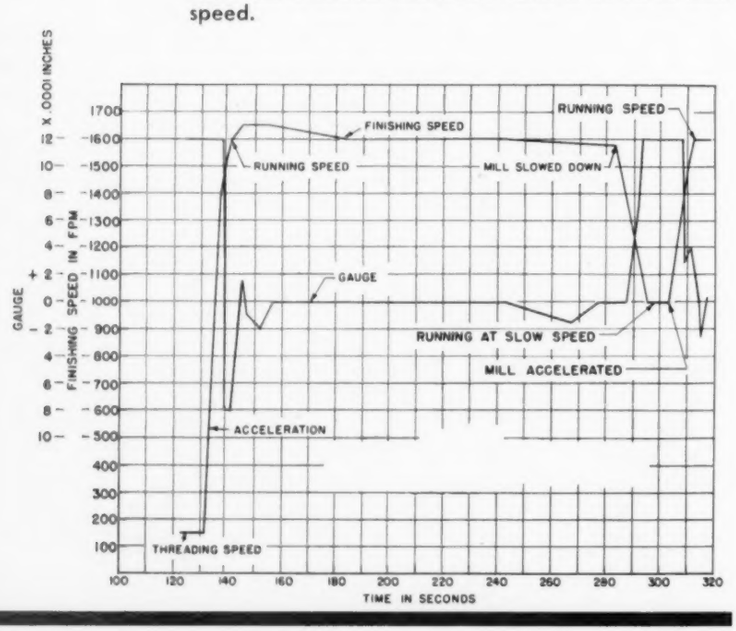
Thus, the control attempts to do just what a skillful operator does with the hand operated vernier rheostat described previously.

Such a control is shown in Figure 2, which is the complete control with the exception of the motor operated rheostat, which is, of course, mounted separately. Such an equipment is in service, but has not operated long enough to obtain comparative results with the manual control. If, in order to maintain gauge, the tension goes above or below predetermined values, as indicated by the tensiometer, the control is automatically taken out of service and a signal given to call the operator's attention to the fact that an adjustment of screws is necessary to stay on gauge. This control, if it proves of sufficient merit, may eventually be connected up to screws so that they can be adjusted when the limits of tension are exceeded. It should not be construed that this is a cure-all. If the mill is not set up properly and the operator cannot manually control gauge, neither can the automatic gauge control it. This control appears to have very good chances of being a success. It may not be able to do an ideal job, but at least it will always be watching and attempting to do its job.

Since, as described previously, the main cause for variations in gauge while at running speed is the variation in incoming strip, it would seem logical that the duty on the automatic gauge control just described would be materially decreased and therefore be considered a vernier adjustment if the gauge delivered from the second stand were maintained as nearly constant as possible. An automatic gauge control, such as that just described, can be used to automatically adjust the speed of the first stand and therefore the back tension on the second stand, so that approximately constant gauge can be maintained out of the second stand. This would of course require a continuous gauge between stand No. 2 and No. 3. The reason for maintaining gauge out of stand No. 2 rather than stand No. 1 is the well known fact that gauge can be controlled more effectively by back tension than by front tension. This fact can be readily demonstrated on a reversing cold strip mill.

So far, gauge control, while at running speed only, has been discussed, and from practical experience it is believed that with a mill set up properly, and either a man or the automatic gauge control on the job, there should be very little "off" gauge during this time. Of course, if it takes a mill crew half a coil to get on gauge when they change rolling schedules, the per cent "off" gauge goes up tremendously. This should never occur, however, if a record is maintained of the speed and load on each stand and the tensions between stands; if the incoming strip is anywhere near uniform; and if the lubricant and cooling solution is correct. In any event, however, the electric equipment, plain or fancy, cannot give good gauge on an incorrectly set up mill.

FIGURE 4—Curves showing variation in gauge with speed when mill is slowed down and allowed to run at slow speed.



VARIATIONS IN GAUGE DURING ACCELERATIONS AND DECELERATIONS

Although the factor of prime importance that causes variation in gauge while running appears to be variations of the incoming strip, this factor slips into the background and the combined effect of variations caused by different rolling speeds becomes predominant during acceleration and deceleration. It is an observed fact, and proven by practical experience, that if a mill is set up to be on gauge at a certain speed, and if the screw settings, cooling solution, lubrication, etc., are

left fixed, the gauge will become heavy if the speed is decreased, and light if increased. This is true, whether of a transient nature, such as during acceleration and deceleration, or a steady state condition.

Figure 3 is a graphic representation of an actual test to substantiate this point. This mill was set up to be on gauge at 100 per cent speed, and screws, etc., were not tampered with during this test. The gauge was so heavy that the instrument recording it was off scale at threading speed. Then as the mill accelerated, it came on gauge as the mill came up to speed. Due apparently to a thin or soft place on the incoming strip, the gauge suddenly started to run light, and the operator slowed down the last stand. He overcorrected, and the gauge went heavy. He then pulled on gauge, by speeding up the last stand. The whole mill was then slowed down to approximately 32 per cent speed, and the gauge became so heavy that the recording instrument went off scale. The mill was immediately accelerated and came back on gauge. Again on deceleration at the end of the coil the gauge went off scale on the heavy side.

In order to make sure this was not a transient condition incident to rapid acceleration and deceleration, the test data shown on Figure 4 was taken. The mill was slowed down and allowed to run for an appreciable time at the slow speed. It will be noted that here again the gauge went off scale on the heavy side, and stayed there all the time the mill was at slow speed. On a repetition of this test, it was found possible to get on gauge at the same slow speed by bringing the screws down about .0005 in. on next to the last stand, and increasing the tension slightly. It was not possible to do it by tension alone between the last two stands, because it would have taken a dangerously high tension to do so.

There seems to be a hazy idea that this is due to the inherent characteristics of the electric equipment, such as loss of tension between stands, or poor speed regulation of the motors at the lower voltage. This was thoroughly disproved practically by first keeping the tensions approximately constant, and then by materially increasing them at the slow speed. Even under these conditions the strip became thicker at the slower speeds, but with this increased tension, the mill came on gauge quicker during acceleration and stayed on longer during deceleration.

Still another group of tests was run, and the results are shown in Figure 5. An accurate differential speed recorder was used to read the differential speeds between the last two stands of a tandem mill. It will be noted that although only a 1 per cent differential in speed was recorded, a maximum of 25 per cent variation in gauge was obtained over the early portion of acceleration. Thus, even though exact speed regulation were maintained, it would not be sufficient to have brought the material on gauge. However, it would have been in the right direction.

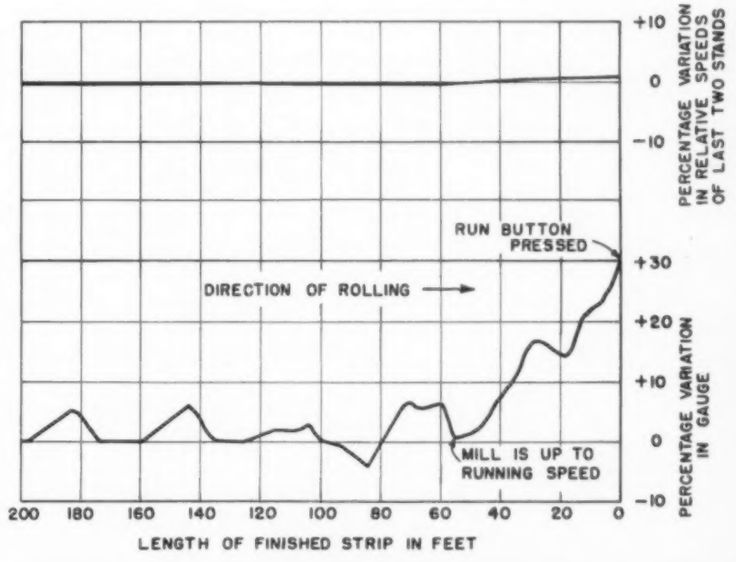
Therefore, it is apparent that the electrical variations are not predominant, but other causes which are inherent in the mill or the steel itself, and which are a function of speed, are of major importance.

Apparently there is no clear and exact explanation of this phenomenon, and if there is, the author has been unable to uncover it. In face of this, it may not be presuming too much to hazard an explanation of possible causes.

It is impractical to make a backing-up roll as hard as the working roll, and it must be recognized that the backing-up roll is a plastic. Indentation of the working roll into the backing-up roll is a function of time which is readily proven in practice. It is a well known fact that if a mill is stopped and allowed to stand an appreciable time with the same pressure used while at rolling speed, the working roll will sink into the backing-up roll. This indentation may be so great that it can be felt and heard for a long time after the mill is restarted. On the other hand, if the mill is stopped and restarted immediately, this does not occur, at least to a visible extent. It is not beyond comprehension therefore that this same phenomenon takes place to a less degree during acceleration and deceleration. A .001 in. variation in diameter of a 50 in. backing-up roll is only .002 per cent, but a .001 in. variation on .010 in. thick strip is 10 per cent.

Probably 80 per cent of the input to a motor goes into heating the strip and the working rolls. The cooling solution, of course, is controlled as to incoming temperature and quantity, so that after the mill has come up to a leveling off temperature, this heat is carried away as fast as it is applied. Otherwise, the temperature of the mill would continue to rise until all the heat could be dissipated by natural radiation. Now, if the same amount of cooling solution is used on the mill during deceleration as while running, and since the energy which goes into heat decreases as the mill slows down, the rolls will be cooled slightly on deceleration. On a specific rolling schedule it was approximated that each 20 in. diameter work roll would decrease .0003 in. in diameter, or a total of .0006 in. for the two. This would mean a 6 per cent decrease in thickness on a .010 in-thick strip. It is admitted that the above approximation was not a profound calculation taking into account temperature gradients, variation of radiation with

FIGURE 5—Curve giving additional test data on the relation between variation in gauge and in speed.



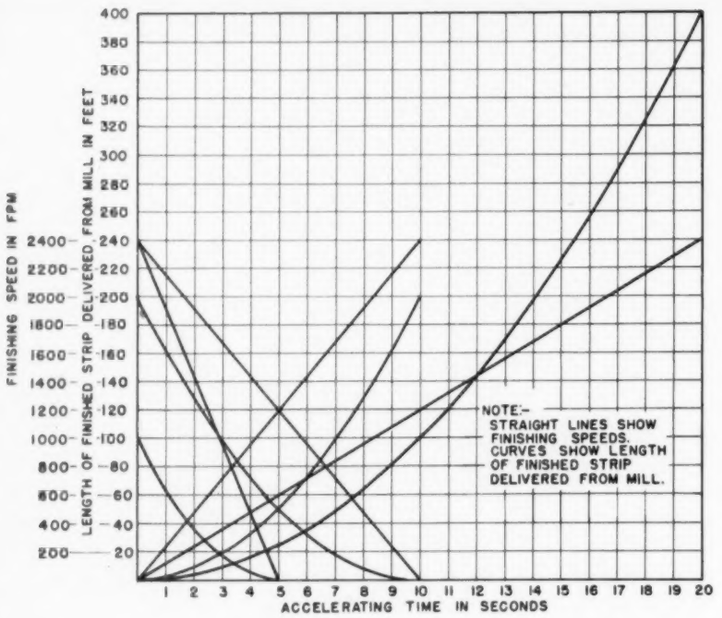

FINISHING SPEED IN FPM
LENGTH OF FINISHED STRIP DELIVERED FROM MILL IN FEET
ACCELERATING TIME IN SECONDS
NOTE:-
STRAIGHT LINES SHOW FINISHING SPEEDS.
CURVES SHOW LENGTH OF FINISHED STRIP DELIVERED FROM MILL.

FIGURE 6—Showing relation between accelerating and decelerating rates and corresponding finishing speeds, as well as finished strip length.

speed, etc.; but the possible order of magnitude is interesting and may be causing more difficulty than ordinarily recognized.

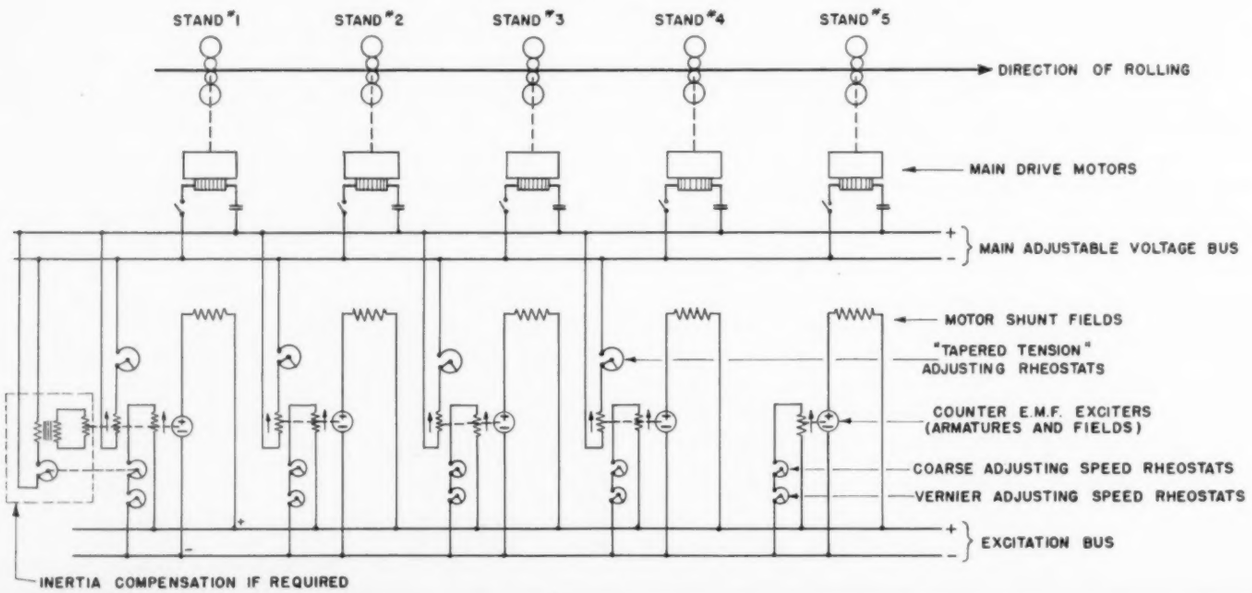
It is common knowledge that more reduction can be obtained with roll lubrication, and that quantitively one is a function of the other. It is conceivable therefore, that the lubrication film may have some relation to speed. It has been definitely established in connection with tests on oil lubricated sleeve bearings that the thickness of the oil film increases with speed. If this were also true in connection with a lubricated roll, it would mean that greater reductions would be obtained at high speed than at low speed. This same phenomenon applies to the oil film in the bearings with the same ultimate result.

The steel itself is a plastic and "in flow" while rolling, and the elongation obtained may have some relation to time. In drawing operations we know from practical experience that it is more difficult to start the elongation than it is to keep it going once it is started. In making bolts, it is found that if the heading operation follows immediately after the drawing operation, no intermediate anneal is required. On the other hand, if a rod is drawn and allowed to lie around for a day, it must be annealed before it can be successfully headed. Thus, permanent deformation is, in all probability, a function of time.

It would, of course, be more desirable to eliminate the causes for variations in gauge than try to correct for them. However, with the present state of the art, this does not seem immediately practical. Therefore, can anything be done electrically to reduce the waste caused by off gauge during acceleration and deceleration? Within limits, something can be done to reduce this off gauge.

From the discussion so far it would appear, therefore, that the main potential saving in off gauge is that which occurs during acceleration and deceleration. This is borne out very conclusively by observation and practical experience. If you will stand at the shearing and

FIGURE 7—Simplified diagram showing the principal connections for a 5-stand tandem mill with tapered tension control.



classifier line of a modern mill and watch the sheets which are thrown out for off gauge, you find that they occur on the ends; very seldom in the center of the strip. Any modern mill with just straight shunt wound motors and no fancy control whatever will get on gauge just as the mill comes on speed, and usually sooner. However, let it be assumed that all of the strip passing through the mill during acceleration and deceleration is off gauge. How much strip does this amount to, and what can be done about it?

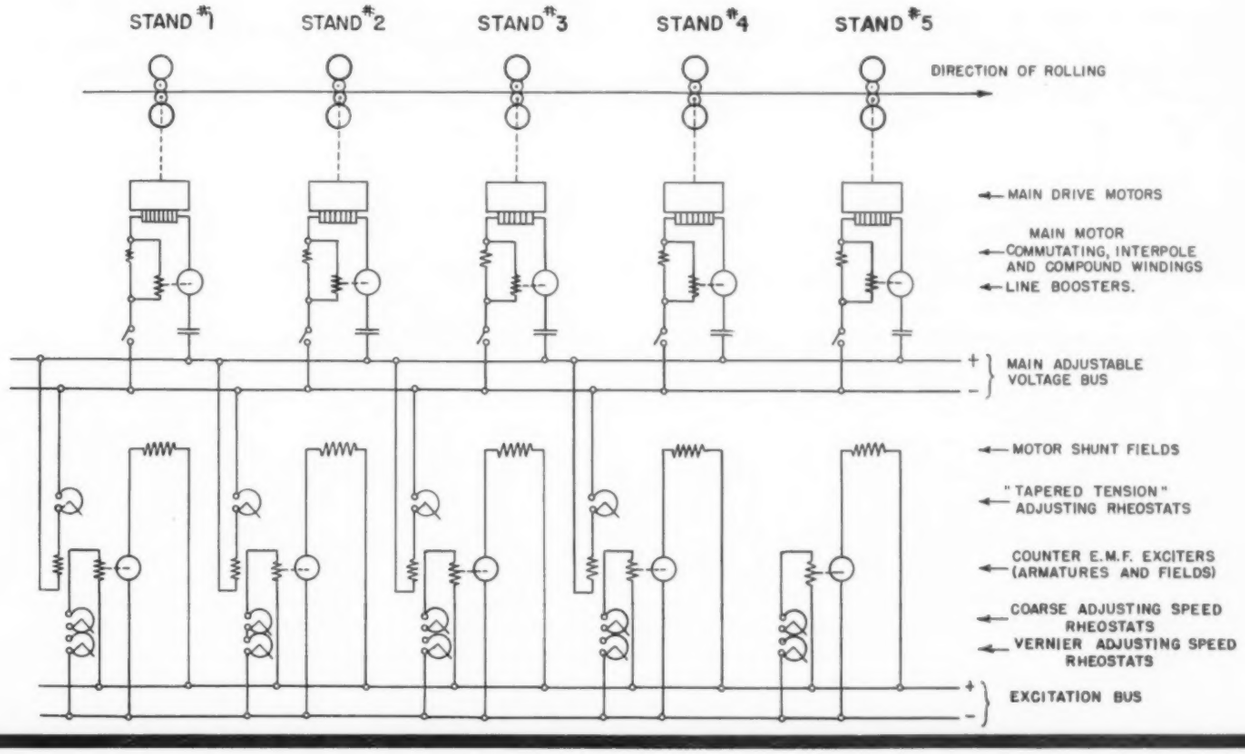
For the purpose of illustration let us take the worst practical case—a 5-stand tin plate mill accelerating to 2400 ft. per min. in 20 seconds, and deceleration in 10 seconds. There is nothing phenomenal in this accelerating and decelerating time, and can be done without too much care in matching inertias of the motors, striving for very low inertias, etc., and without any fancy control. Figure 6 shows the strip that has passed through the last stand at any point in the acceleration period. It will be noted that 400 ft. of strip has passed through the finishing stand during acceleration and that 200 ft. of strip passes through the last stand during deceleration. This makes a total of 600 ft. delivered from the mill during both acceleration and deceleration. Nearly every modern tin plate mill rolls 6000 pound coils, which represents approximately 6000 ft. of finished strip. Thus, the potential per cent off gauge strip is 10 per cent. However, if 12,000 pound coils are rolled, this becomes 5 per cent.

Now, however, if we build the motors with low and matched inertias, or rather stored energies, we can accelerate this same mill in 10 seconds and decelerate it in 5 seconds. This has been done quite successfully without any fancy control whatever, even with motors requiring 60 per cent current to accelerate them. It would be preferable of course, to select motors with low enough speeds and inertias, so that it requires from 30 to 40 per cent current to accelerate them. With such motors it is quite simple to accelerate in 10 seconds and decelerate in 5 seconds. With these rates, it will be noted from Figure 6 that only 200 ft. of strip passes through the mill on acceleration and 100 ft. on deceleration. Based on a 6000 lb. coil, this represents a potential of 5 per cent off gauge, and based on a 12,000 lb. coil—2½ per cent. It therefore seems sensible that the first consideration in reducing off gauge is to make the mill inherently correct by obtaining fast accelerating and decelerating rates and using as large coils as possible. This cuts the potential off gauge to a minimum before any thought of fancy control is considered. Not only is this accomplished, but the possible production rate is increased also.

Before delving into ways of getting on gauge before we get up to speed and the special control required, let us discuss briefly a reasonable rule for selecting motor ratings to give desirable accelerating characteristics.

Of course, lower accelerating currents can be obtained by using lower speed motors, or further still by using double armature motors. In addition, inertias can be decreased by 40 degree or even 60 degree class "B" insulated motors, based on forced ventilated ratings. How far should this be carried? As a good general rule

FIGURE 8—Simplified diagram showing the principal connections for a 5-stand tandem mill with line boosters and tapered tension control.



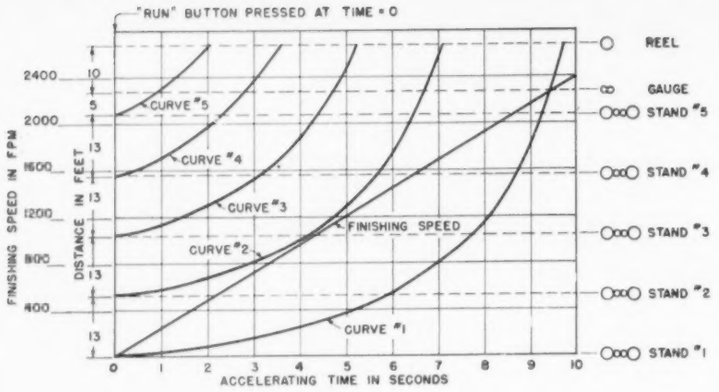


FIGURE 9—Curves showing the progress of a point on the strip during acceleration beginning at the various stands, when the "run" button is pressed.

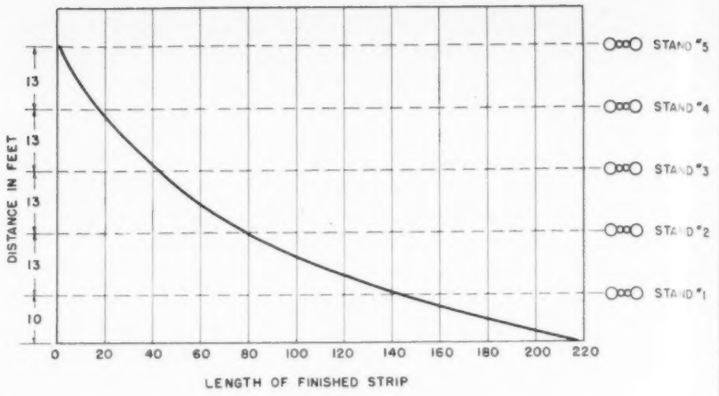


FIGURE 10—Curve showing the steel between the various stands in terms of finished steel for typical tinplate reduction schedule.

the motors should be rated on a 40 degree force ventilated basis, and with speeds so selected that the current required to accelerate motor and mill to maximum speed in 10 seconds is of the order of 40 per cent of normal full load current. Such an accelerating current involves no difficult control problem. This is borne out by actual results and not theory. A mill is in quite successful operation at the present time which is being accelerated to 1900 ft. per min. in 10 seconds and requiring 60 per cent accelerating current. Thus, in setting the limit of 40 per cent as above, there is a considerable margin of safety from a control standpoint. In addition, the value of 40 per cent has not been arrived at arbitrarily. Standard steel mill motors are guaranteed for frequently repeated peak loads of 150 per cent at maximum speed and 175 per cent at full field speed—based on a 2:1 speed range motor. Thus, assuming that a selected motor will be called upon to operate at full load and maximum speed for every coil, it will require 140 per cent current during acceleration for each coil. Here again we have a margin of 10 per cent as a safety factor.

In addition, the 40 degree force ventilated rating is not suggested at random. The 40 degree motor carries the usual 125 per cent load guarantee for 2 hours, but the 60 degree motor with class "B" insulation is maximum rated and does not carry this additional margin. It would seem, therefore, that this margin should be maintained in general as an ignorance factor and for possible changes in rolling practices.

Of course, there are exceptions to all rules. For instance, it might be found that in meeting this general rule a motor would be selected with such a speed that with only a slight increase in the cost of the motor, a gear might be eliminated, resulting in a net saving. Again, with certain combinations of horsepower and speed, a real saving can be made in inertia or stored energy by using 60 deg. motors, making it possible to use higher speed motors at an appreciable saving in cost; in this case the margin of safety might be reduced for the sake of economy.

Another important factor which should not be overlooked in selecting the motors so they will be inherently correct, is to taper their ratings in accordance with the actual schedules to be rolled.

At the National Convention of the Association of Iron and Steel Engineers in 1938, M. J. Leding and T. R. Rhea gave a very complete discussion on the problems involved in accelerating and decelerating tandem mills, and these problems will not be repeated here. Suffice it to say that from a practical standpoint it has been proven that a mill can be accelerated and decelerated quite successfully by merely selecting the WR^2 of the motors and balancing the line resistances with reasonable care. When the motors are selected properly no inertia compensation whatever is required. When it is required, however, the currents for accelerating the motors can be controlled with such small variations that they become negligible.

The control for accomplishing this, when required, is quite simple. The current required to accelerate a motor depends upon its field strength and the rate at which the armature voltage is increased. Therefore, if a small rheostat (Figure 7) which is operated at the same time the motor field is adjusted, is connected in series with the primary of a transformer which is in turn connected across the motor armature voltage, the secondary current of the transformer will be proportional to the rate of acceleration of the motor. This secondary current, if applied to the field of a counter-electromotive force exciter in the motor field, will cause the motor armature current to change proportionately. Therefore, the current for acceleration is readily controlled. Once this adjustment is made, it requires no further attention.

Thus, shunt motors which do not require more than 40 per cent current to accelerate the mill in 10 seconds and indicating tensiometers may be considered as the basic electric equipment for good gauge control during acceleration and deceleration.

Now, what special control can be used to attack the remaining off gauge? From the foregoing discussion of the causes for variation in gauge, it is obvious that the only way to attack the increased thickness at lower speeds is to increase tension during acceleration and deceleration or operate the screwdowns. Furthermore,

since gauge is a function of speed, the tension should be greater at threading speed, and gradually taper to the running value as the mill is accelerated up to running speed.

This may be accomplished in either of two ways: By counter-electromotive force exciters in the motor fields, or by booster generators in series with the motor armatures.

The former is quite simple and is shown in elementary form in Figure 7. It will be noted that it consists of a rheostat in the field of a counter-electromotive force exciter, the armature of which is connected in the motor field. The excitation for this counter-electromotive force exciter field is taken from the voltage applied to the motor armatures. The polarity of this exciter is such that when its excitation is decreased, the field of its corresponding motor is strengthened, and slows down, which increases the tension between the stand which it drives and the stand which follows it. The connections are such that the tension decreases as the mill is accelerated. Likewise on deceleration the excitation is increased, and therefore the tension between stands is increased. It will be noted that the last stand does not have such control because it is used as the master drive. This same exciter is used for inertia compensation, a separate field being used for this purpose, as shown in Figure 7.

The advantages of line boosters have been recognized for a long time and have been discussed before this Association previously. They are not a newcomer to the field, and have been used as early as 1931 in connection with tension reels, tension devices, or pullers and feed reels. Theoretically they are the most perfect means of control, especially at low voltages. It is a well known fact that if motors had no internal resistance they would accelerate exactly in synchronism with voltage. This would mean that constant relative speeds would be maintained on a tandem mill during acceleration and deceleration and at any intermediate speed. This effect can be approached by series line boosters, bearing the following in mind.

The effect of internal resistance is to slow down a motor with load while the armature reaction tends to make it rise. Thus, the speed regulation on the motor depends upon these two opposing factors—along with such other things as current distribution in the brush face, etc. This means that if a full compensation for internal resistance were made, the motor would have a rising speed characteristic, and if there is anything a tandem mill abhors, it is a rising speed characteristic. Thus, when compensating for IR drop, to obtain the desirable zero resistance characteristic, it is necessary at the same time to use a series field on the motor which will give it a slightly greater droop than the internal drop acting alone would give. Then a complete compensation can be made for internal drop by booster voltage and still have a slightly drooping speed characteristic, say 1 or 2 per cent to be on the safe side. The booster can then be excited by connecting its field across the commutating and interpole field winding of the stand motor with which it is used. Thus, its voltage will be proportional to the load on the motor, and a complete compensation for internal drop would be made automatically. This would, of course, mean that the motors would have very nearly the same speed regulation at all voltages, and the special compensation for inertia control would not be required. The motors would then accelerate and decelerate together and constant relative speeds would be maintained.

From an inherent set-up standpoint, this is just what is wanted. However, it has already been brought out that the combined effect of the causes of variation in gauge during acceleration, deceleration, and running speed operates so that although constant relative speeds tend to give constant gauge, it does not do a 100 per cent job of it. Actually constant relative speeds fall far short of doing the job during acceleration and deceleration. This was clearly shown in Figure 5.

Thus, even though line boosters are used, it is necessary to provide some special control to obtain "tapered tension" during acceleration and deceleration. Now, if series boosters are used for this purpose, it is necessary to raise their voltage at threading speed, and gradually reduce it as the mill accelerates to "running" speed. Since the boosters are excited from their own load, however, it would be necessary to sacrifice some speed regulation to prevent a rising characteristic during acceleration. This would, of course, disturb the inherent set-up and sacrifice speed regulation at running speed It would be better, therefore, to set the boosters for the best inherent regulation possible and apply the tapered tension field control the same as before.

The choice between the two systems of motor field control versus line booster control is unfortunately not a clear cut one. From an engineer's viewpoint, the line booster is unquestionably the more perfect system, but in all fairness to the steel industry, the benefits to be gained by them may not justify the additional first cost or the maintenance involved in these large low voltage machines. The greatest benefit of line boosters is at very low voltages, and so far it would appear that the savings in off gauge here are almost negligible. An installation is now being made, and it is hoped that the benefits gained will well offset the cost and maintenance.

Now, after we have the special control, what can we hope to do with it? From observed tests, after averaging a lot of records, it would appear that the following results might be expected as a general rule. With the basic equipment described, the mill will be on gauge at about 90 per cent speed on acceleration, and will stay on gauge down to about 60 per cent speed on deceleration. If the same equipment is used, but the tension manually increased between the last two stands by means of the vernier rheostat for the last stand, the mill will get on gauge at about 80 per cent speed and stay on gauge down to about 40 per cent speed. Now, if tapered tension control is added on gauge will be obtained at 50 per cent speed accelerating and hold on gauge down to about 15 per cent decelerating.

Experience may prove that this can be bettered. However, this depends largely upon the finished gauge, type of steel, brittleness, and extent of edge cracking. To go much beyond this may run into excessive breakage. One break offsets a lot of saved off gauge because it means wrecked rolls and lost production.

In order to give some idea of what it means to get on gauge at various speeds, Figure 6 may be referred to. With "standard" equipment it was possible to get on

gauge at 80 per cent or 1920 ft. per min., and hold gauge down to 40 per cent of 960 ft. per min. From the curves in Figure 6 it will be found that this would mean 128 feet off gauge on acceleration and 16 feet off gauge on deceleration. This is a total of 144 ft., and based on a 6,000 lb. coil, is 2.4 per cent off gauge, or 1.2 per cent based on 12,000 lb. coil.

With special tapered tension control it was possible to get on gauge at 50 per cent speed, or 1,200 ft. per min. on acceleration, and stay on gauge down to 15 per cent speed or 360 ft. per min. on deceleration. From the curves in Figure 6 it will be noted that this represents 50 feet and 3 feet of off gauge respectively. On the basis of 6,000 lb. coils this is .9 per cent, or on the basis of 12,000 lb. coils, .45 per cent. It is to be recognized that with slower speed mills accelerating and decelerating in the same times as the illustration just used, the potentia off is relatively less.

It cannot be too strongly emphasized, that how closely these values can be obtained, depends on how the mill is set up, and how much tension the strip will safely stand. The tension the strip will stand is not the elastic limit necessarily, but depends to a much greater extent upon the degree of edge cracking, which is always present, and upon many other factors, such as roll contour. A strip which is over-rolled in the center transfers practically all the tension to the outside edges. Again, if a mill is not "stuck" squarely, the tension is concentrated in one side. The allowable tensions vary with every schedule. Therefore, if the operators are to do a real job of reducing off gauge during acceleration and deceleration, the rheostats for adjusting the amount of tapered tension should be located on the mill housing, where he can adjust them. It is obvious that he should be able to read the tension between stands, otherwise the "tapered tension" control would be almost useless.

A study of the times involved and the distance steel moves in the mill during acceleration and deceleration is also essential to the proper understanding of what rapid acceleration and deceleration mean, and its relation to controlling gauge, as well as to production. As an example, a 5-stand mill placed on 13 ft. centers, accelerating to 2400 ft. per min. in 10 seconds, and decelerating in 5 seconds, will be assumed.

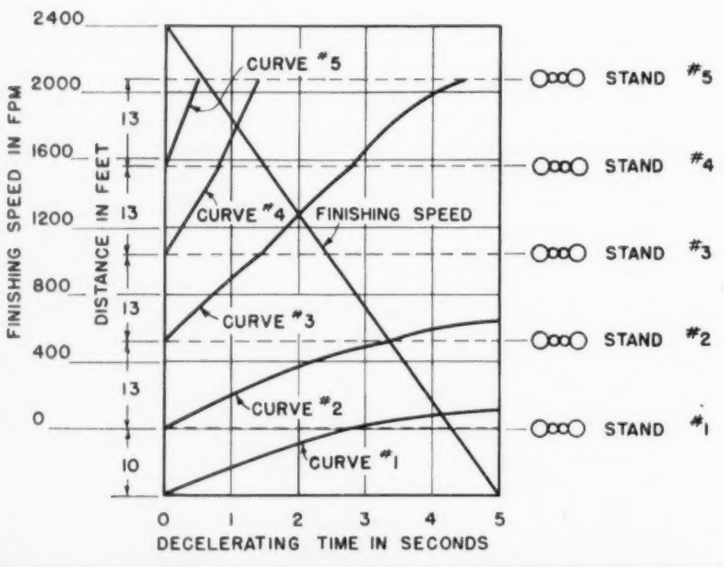
Figure 9 shows the progress of a point on the strip as it moves through the mill during acceleration. Curve No. 1 shows the movement of a point through the mill starting at stand No. 1 just as the "run" button is pressed, curve No. 2—a point starting at stand No. 2 when the run button is pressed, etc. It will be noted that it takes approximately 6 seconds for a point starting at stand No. 1 to reach No. 2 stand. Thus, any correction, such as tension or screwdown, made on No. 1 will not reach No. 2 stand until 6 seconds later, and by this time all of the steel between stands No. 3, 4 and 5 has passed through the finishing stand. Therefore, any correction, to have been effective, would have had to be made as the steel passed through No. 1 stand while threading it.

Thus, in order to attack the inherent heavy gauge which occurs during acceleration, it might be well to arbitrarily lower the screws on No. 1 stand on threading, and then raise them to the normal position as the strip entered No. 2 stand This amount of steel, it must be recognized, is rolled without tension, because tension cannot be obtained until it enters stand No. 2. It is also almost enough steel to reach the finishing stand, as may be determined by referring to Figure 10.

Figure 10 shows the steel between the various stands in terms of finished steel for a typical tin plate schedule. It will be noted that the steel between No. 1 to No. 5 stands inclusive represents 144 feet of finished strip. For the reference above it will be seen that the steel between No. 1 and No. 2 stand represents 144 minus 78, or 66 feet of finished strip, while that between No. 2 and No. 5 inclusive represents 78 feet of finished strip. Thus, if this amount of strip were reduced sufficiently as it passed through No. 1 stand, it might be possible to get on gauge almost immediately. This may or may not be fully realized, but should surely be tried religiously until it can be conquered and used as a regular rolling practice. This has been done manually and can readily be done automatically with fairly simple follow-up control.

Right here it would be well to mention incoming gauge again. The incoming gauge varies not only throughout the length of the coil, but very materially from one coil to the next. Although this is true, it would be preferable to have it come out of No. 1 stand at the same gauge all the time. While one coil is being rolled, the operator has time to mike the end of the next coil. Therefore, if automatic follow-up control were used with 2 dials, one for setting "normal" position and the other for setting the arbitrarily "lower" position, he could make these two settings while the coil in the mill is being finished. As the tail end of the coil left stand No. 1, he could press a separate push button, or it could be a function of the "thread" push button, and the screws would automatically go to the lower position. Then as the strip entered No. 2 stand, a load relay

FIGURE 11—Curves showing progress of a point on the strip during deceleration beginning at the various stands, when the "thread" button is pressed.



would cause the screws to return to the normal position. It is believed that with experience he would become very adept at making such arbitrary pre-settings, and it would surely be closer than the present method of doing nothing about it.

This same type of follow up control might well be used in connection with the last stand when the rolling practice used makes it necessary to raise the screws as the tail end of the strip comes through in order to prevent pinching and tail marking. This would not only relieve the operator, but would also automatically return the screws to the same setting each time.

Figure 11 shows the progress of a point on the strip through the same mill while decelerating in 5 seconds. A study of this is most important in reducing off gauge and threading time. It will be noted that if the thread button is pressed when the tail end is 10 feet ahead of No. 1 stand, the tail end has just passed through No. 1 stand when the mill is completely decelerated. If Figure 10 is now referred to, it can be seen that the steel left in the mill at this time is equivalent to 128 feet of finished strip. All of this strip is definitely off gauge. Furthermore, all of this strip must be run out of the mill at threading speed 200 ft. per min., and this would require 38 seconds. Thus it would take 43 seconds to clear the mill after the thread button was pressed and at least 128 feet of scrap unless the screwdowns were changed and tensions increased materially.

Now if the thread button were pressed just as the tail end of the strip left stand No. 1, 68 feet of strip would be left in the mill and it would take 20 seconds to run out this strip or a total of 25 seconds to clear the mill. However, if the "thread" button is pressed as the end of the piece leaves stand No. 2, it will be noted that the end will clear the last stand just about the same time the mill decelerates to the threading speed. In this case only 5 seconds is required to clear the entire mill and the off gauge should be almost negligible.

Now suppose the decelerating time is increased to 10 seconds instead of 5. Figure 12 shows the progress of a point through the mill starting at No. 1 stand, when the thread button is pressed and the mill is decelerated in 10 seconds. Here it will be noted that the mill is cleared in 7.5 seconds and in 2.5 seconds additional time the mill is completely decelerated. Thus, as strange as it might seem, if the thread button is pressed in both cases just as the end of the strip leaves No. 1 stand, the mill will be cleared in a shorter time and with less off gauge when the mill is decelerated at a slower rate. This gain is very appreciable—with the comparative cases just given, the relative times are 7.5 seconds as compared to 25 seconds. Thus by the simple expedient of slowing down the rate of deceleration, a saving of 17.5 seconds can be made per coil and the amount of off gauge materially decreased. Of course a slightly greater saving from 7.5 to 5 seconds could be made by using the higher rate of deceleration and if the thread button is not pressed until the tail end leaves No. 2 stand. This means a higher average speed through the mill and may not be as practical because the operator feeding the mill usually presses the thread button and it would be difficult for him to tell when the end leaves No. 2 stand. This, of course, might be done automatically, but it is doubtful whether it would be worth while. The most practical rule would be to press the thread button as the

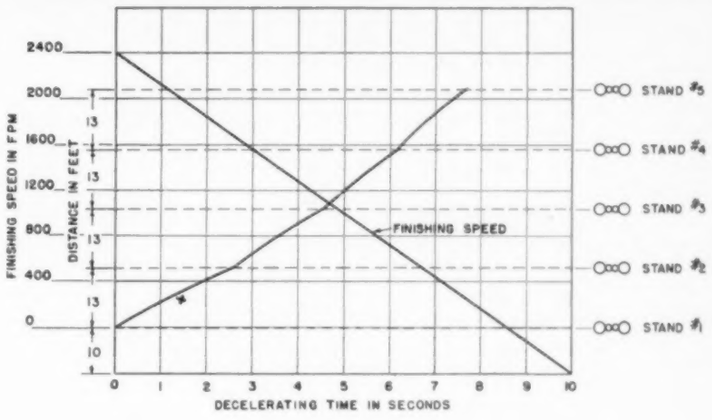


FIGURE 12—Showing progress of a point on the strip during deceleration beginning at stand No. 1 when the "thread" button is pressed.

end leaves No. 1 stand and to adjust the decelerating rate so that the mill just reaches threading speed as the end leaves the last stand.

It must be clearly recognized that this very powerful method of reducing off gauge as well as the time required to clear the mill means that the average threading speed in the mill is higher. This may give difficulty in guiding the tail end of the strip and in threading the next piece. The possible saving in time and off gauge, however, should well offset the energy and expense required to perfect adequate means for guiding and threading the mill.

Thus the advantages of raipd deceleration and "tapered tension" may be well offset by improper pressing the thread button.

Recapitulating, the fundamental requirements for good gauge control that should be incorporated in every mill are:

1. Good hot strip.
2. Large coils.
3. Shunt wound motors rated on a 40 degree force ventilated basis and in accordance with the schedules to be rolled; and, with speeds and inertias so selected that a maximum of 40 per cent current is not exceeded when accelerating them together with their respective mills to maximum speed in 10 seconds.
4. Tensiometers for indicating the tension between stands.
5. Vernier rheostats for accurately adjusting the speeds and therefore the tension between stands.
6. "Tapered tension" control for obtaining increased tension between stands at threading speed and gradually tapering it to the running value as the mill is accelerated to the running speed.
7. Inertia compensation when higher than recommended acceleratng currents are used or when the inertias of the motors are not matched properly.

Additional requirements if the maximum assistance is to be given the operator for maintaining gauge are:

8. "Automatic gauge" control following the second and last stands.
9. Screwdown folow up control for No. 1 stand, as well as the last stand if rolling practice requires the raising of the screws at the end of each coil.
10. Line boosters.

In conclusion it is safe to say that if a mill is completely equipped with the electric equipment outlined and good rolling technique is used, the results will be quite surprising. However, poor rolling practice can cause more off gauge than all the electric refinements can possibly save. The electric cures can assist, but are not cure-alls.

DISCUSSION

PRESENTED BY:

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F. MOHLER, Industrial Department, General Electric Company, Schenectady, New York.

S. J. MIKINA, Research Department, Westinghouse Electric and Manufacturing Company, East Pittsburgh, Pennsylvania.

G. E. STOLTZ: Mr. Mohler has given quite a comprehensive discussion of the various factors that may contribute to off gauge on a cold strip mill. As he mentions in his paper, there are a number of things that contribute to off gauge, and as yet it is a subject that is not well understood, so that there is some question as to whether successful maintenance of gauge will be obtained until we have a better understanding of the causes of off gauge and are in a position to control them.

To install means as described by Mr. Mohler to control gauge by tension without understanding all the factors that cause off gauge and have them under control would be like putting a voltage regulator on a generator without giving much thought as to whether the characteristics of the generator are such that they would respond to the action of the regulator.

There are two ways of approaching the correction for ffo gauge during reduced speeds, one as described by Mr. Mohler of having fast acceleration and retardation, and the other is to make some attempt to readjust the tension and screwdown settings to obtain gauge at reduced speeds. If fast acceleration and retardation is used, there is some question as to whether it would be better to leave the adjustment of the mill as is, or attempt to effect some change which must be continually modified while the speed is changing. In addition to its not being easy to adjust the tension and screwdown setting with changing speed, particularly when fast acceleration and retardation is used there is a limitation of how high a tension can be used before an increase in the number of breaks occurs. This is not a fixed value as the number of cracks and the extent to which the edges are cracked will have quite a bearing on the amount of correction by tension that can be made.

F. MOHLER: I do not quite agree with Mr. Stoltz's analogy. Although we may not thoroughly understand all of the causes for gauge variation, we have found that we can reduce strip thickness by increasing the tension, and increase the thickness by decreasing the tension. Now, since we can continuously gauge the strip, it does not seem improbable that we can automatically increase the tension when the gauge runs heavy and pull it back on gauge. This is exactly what a man does by hand on any modern mill, and the man, nine times out of ten, has no conception whatever as to why the gauge is varying. Furthermore, he does not care particularly; he is only interested in staying on gauge and not in the theoretical aspects. This lack of understanding of the causes does not hinder him one bit in watching the gauge and varying the tension so as to hold correct gauge.

S. J. MIKINA: I wonder if Mr. Mohler would be kind enough to elaborate a little more on the automatic gauge control, and tell us what accuracy of regulation is possible, and whether in attempting to increase accuracy there are difficulties due to hunting of the regulator?

F. MOHLER: I am glad you brought that point up. The accuracy of the device is as accurate as the indication of the continuous gauge, but the accuracy of the results is another question. As Mr. Stoltz mentioned, there are so many things causing variations in gauge that it is rather difficult to herd all these together and say, "Now this is going to make just so much change in gauge, and we are going to have to change the tension just so much to bring it back on gauge."

For instance, on Bessemer steel, you may have to increase your tension two per cent to bring it back on gauge with a one per cent variation in gauge. On the other hand, on open hearth or soft steel, you might have to increase it only one per cent. We have adjustments on this gauge control for controlling the value of these increment changes in tension. The idea is to make as full a correction as possible for the amount of off-gauge the first time. In other words, the amount of tension change depends upon the amount of off-gauge. But that is not the same for all steels, and even throughout the entire length of a piece of steel it may not be the same.

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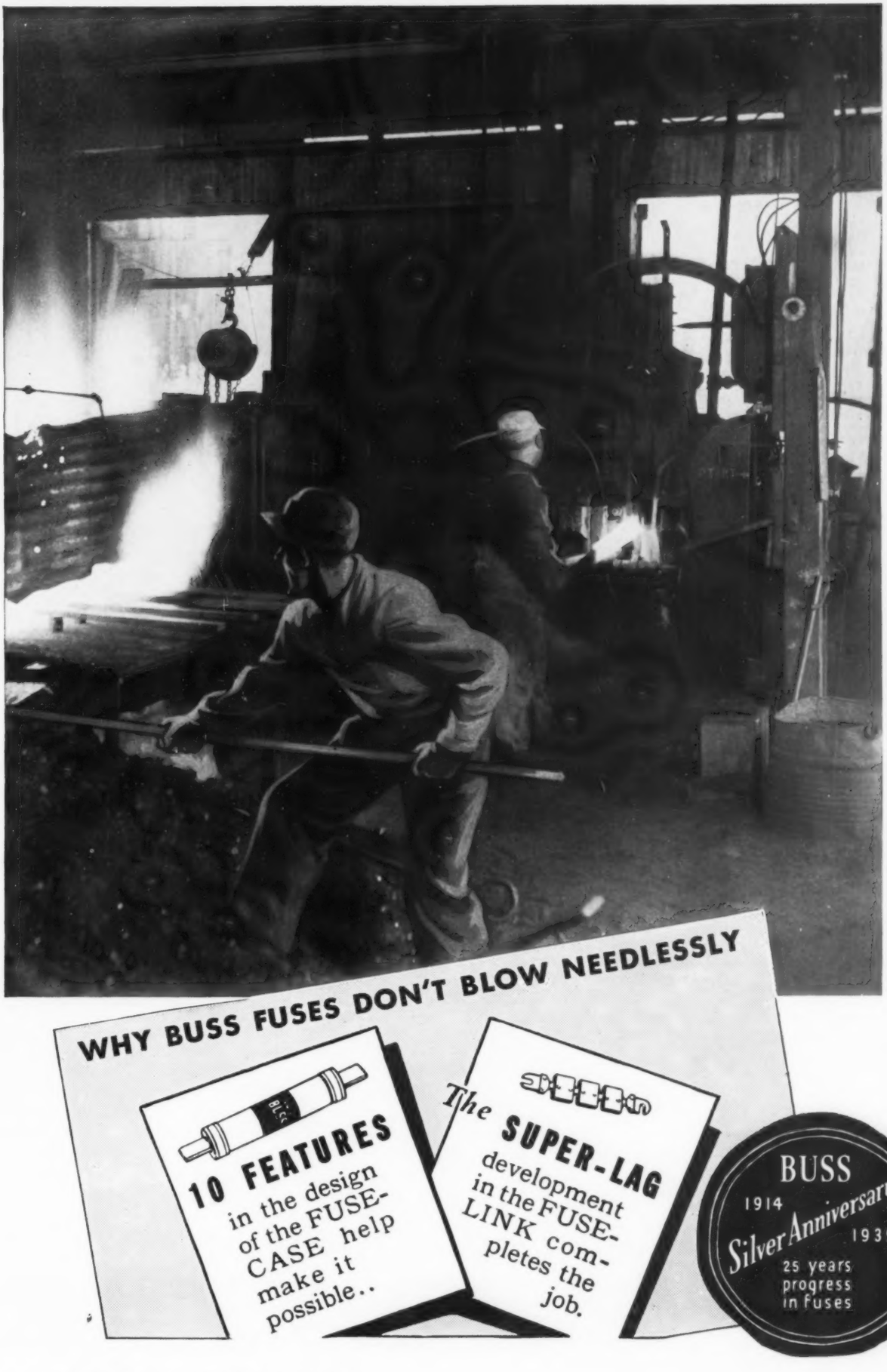
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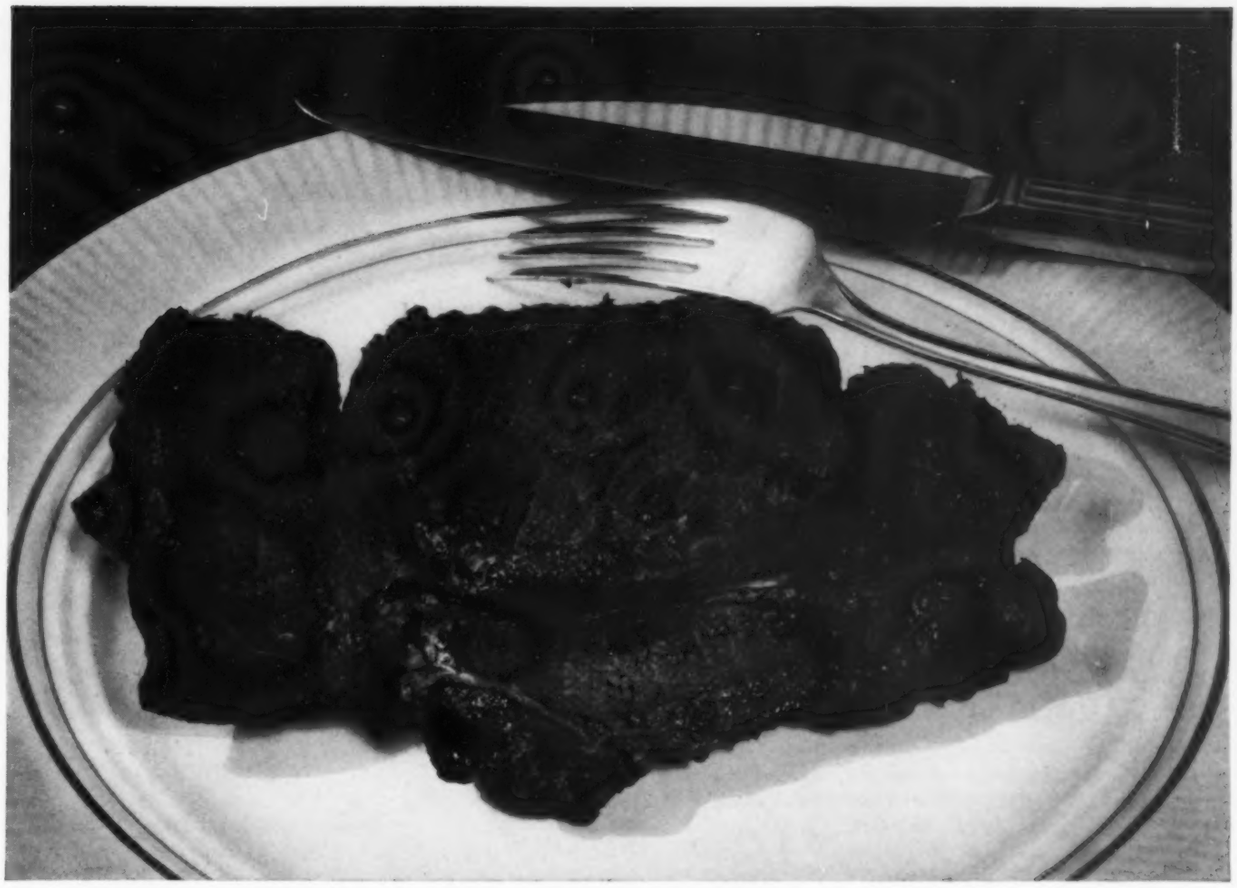

Who wants a CRISP Steak?

If you're like us you want it medium, but the pan-broiled wreck above shows that too much heat can transform a tender steak into a charred cinder in nothing flat.

It's something to think about if you are using wire insulated with organic materials in places where the temperature hits the high spots. Like the steak, the insulation begins to dry out and lose flexibility under continued exposure to heat, finally becoming so hard and brittle that vibration opens up cracks, leaving it just about as moisture-resistant as a piece of cheese-cloth. And when that happens it isn't long before you are hauling out and replacing . . . and you are going to keep it up if you use the same stuff again instead of a 100% heat resistant wire like Rockbestos, designed to give real service in such locations.

Rockbestos asbestos insulated wires and cables won't dry out or crack under heat exposure or with age. Corrosive fumes won't rot their insulation and neither will oil or grease cause it to bloom or swell. These and the rest of the Ten Tested Rockbestos Values will help you reduce maintenance expense and equipment outage as they have helped others. Send for samples and our Catalog No. 10-E. Write to us or our nearest branch office. Rockbestos Products Corporation, 942 Nicoll St., New Haven, Conn.

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NEW DEVELOPMENT MAY REVOLUTIONIZE MANUFACTURE OF STAINLESS STEEL

▲ A machine which produces a new composite metal of tremendous social and economic significance has been licensed for manufacture by the United Engineering and Foundry Company from R. E. Kinkead, consulting engineer.

An entirely new development, the composite metal which will be produced by the new machine, revolutionizes all ideas concerning wearing properties of materials and the cost of obtaining them in the many manufactured and fabricated products which require maximum resistance to wear and ordinary rust.

The new metal makes available, at cost savings of 15 to 20 per cent, wearing qualities which are better and more lasting than those of competitive materials such as tin terne and galvanized steel. While possessing all the advantages of such materials, plus large cost savings, the new metal has none of the disadvantages. The new material is ordinary steel with the surface alloyed by addition of chromium and nickel.

Extensive work, over a period of many months, has been carried out in the production of low carbon steel with an alloyed surface of chromium iron or 18 per cent chromium and 8 per cent nickel stainless steel. The material has been subjected to many fabricating processes and tests to prove the perfection of the bond between the alloyed surface and the base metal, and it has been shown to be suitable for deep drawing, the most difficult of all fabricating requirements.

The surface of the metal is alloyed in the steel producing plant when in the form of an ingot or slab. Ferrochrome is placed on the surface of the ingot. In case chromium nickel alloys are to be made, nickel shot is added. This is covered by a protective furnace slag. Further operation is conducted on the ingot while it is hot, and carbon arcs are used to fuse the alloy and the surface of the ingot. A correct amount of alloying element is applied to result in the desired alloy. Carbon arcs are moved progressively over the entire surface to be alloyed in such a manner as to give a uniform depth of alloy. One or both sides may be alloyed.

The process appears to have economic significance in the field of tin plate. The addition of approximately one pound of chromium to four pounds of iron will produce a chromium iron alloy which, in many respects, is superior to tin in resisting corrosion. The price of the chromium is only $1.25 and the iron eight cents, making a total of $1.33 for five pounds of the alloy. Five pounds of tin are worth approximately $2.25. The actual application of either the tin or chromium alloy surface may be made at comparable costs.

Past efforts to increase the utility and serviceability of steel have taken many forms. Mild steel has been coated with nickel, brass, copper, chromium, tin or zinc—not to mention glass, rubber, paint, lacquer and such non-metallic elements—to make it more resistant to rust. One of the most recent attempts to increase the wear resistance of ordinary mild steel has been to clad it with a thin layer of stainless steel.

While all of these materials represent advances over plain steel in the matter of wear, their availability has been restricted either by their comparatively high cost or by problems encountered in manufacturing or fabricating them into finished products.

Because it provides unsurpassed wearing qualities at substantial cost savings, the new metal is tremendously significant not only to the steel industry but to manufacturers and users of products in the almost unlimited field where the benefits of the new metal will be clearly apparent. The metal can be utilized to increase the durability of countless products which, in the past, have had the limited wearing qualities of ordinary steel. Such products can now be provided the long life of superior wear-resisting metal at a cost much lower than was ever possible, heretofore. Other products which have utilized tin plate, galvanized steel, stainless-clad steel and other competitive materials to assure a long life, can now be manufactured at tremendous savings. Utilization of the new composite metal to the extent justified by its many advantages will create immeasureable benefits.

NEW FIRE BRICK HAS IMPROVED QUALITIES

▲ Babcock and Wilcox Company has recently introduced a new insulating firebrick. Representing a radical improvement in heat-insulating materials, the new firebrick now makes available for the first time a product that has the stability of a fired-clay refractory, and yet weighs less and has insulating values comparable with or superior to unfired insulating materials.

Made of special Georgia kaolin by an exclusive process, these insulating firebrick retain their structure, show negligible shrinkage, and can withstand loading without deformation at temperatures up to 1600 degrees F. for direct exposure and 2000 degrees F. (interface) for backing up. The average weight is only 1.1 lb. per nine-inch straight or approximately 19 lb. per cu. ft. An indication of their effectiveness is shown in the case of a wall of 9-in. dense firebrick backed up with 4½ in. of the new material. The heat-flow loss in such a wall is 76 per cent less than without the backing up.

15 ton (two 7½ ton hooks), 100'-0" span Cleveland all-welded crane in a modern mill. Two other Clevelands in background.

FOR THE HARD JOBS TRY CLEVELANDS

For continuous year in and year out service Cleveland all-welded mill cranes have a remarkable record. Despite severity of service and often-times considerable abuse, Clevelands will be found doggedly at it.

Their all-welded construction insures all parts remaining firm and intact. Usual loosening is eliminated. There is no binding with resultant abnormal wear. All working parts continue to run as smoothly as when the crane is first erected.

Among steel mill engineers who know, who have tried them all, Cleveland all-welded cranes rate high.

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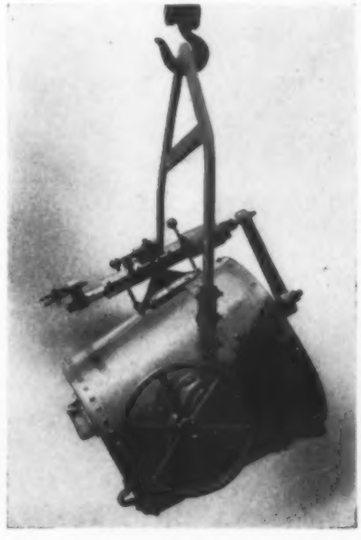
WORM-GEARED LADLES FOR MOLTEN STEEL

▲ A line of worm-geared ladles, ranging in capacities from two to five tons, has been introduced by the Treadwell Construction Company. These ladles are suitable for efficient handling of molten steel and other metals. Salient construction features include a stopper rig for drawing pure, slag-free metal from bottom of ladle and a geared turning device so designed as to prevent any movement of the ladle due to weight of molten metal.

The stopper rig, or harness, consists of a carrier arm, slide, guide, and stopper rod. The latter extends down through the metal to bottom of ladle. It has a sleeve on it made of fire clay or heat resistant terra cotta with graphite plug on bottom. When plug is raised, the molten metal is discharged through bottom of ladle and the slag, which floats on top, is prevented from getting into the ingot mould or casting.

The turning mechanism, which is self-locking, consists of a worm wheel mounted on the ladle trunnion and

This four-ton ladle, constructed of steel plate, is suitable for the handling of molten steel.



integral with the bail. This gear in turn meshes with a worm of sufficiently low pitch to prevent any movement of the ladle. The hand wheel is mounted on a cross shaft with suitable gear for operating the worm. Roller type bearings are used and the entire mechanism is mounted in an oil tight case so designed that all gears operate in an oil bath.

One example of these new ladles is a four ton ladle suitable for handling molten steel. It is made of $\frac{3}{8}$ in. steel plate, is 4 ft. high and 4 ft. in diameter. Similarly constructed ladles with less gear clearance are available for handling molten tin, babbit, lead, zinc, etc.

NEW MAGNETIC DRIVE AIDS SPEED CONTROL

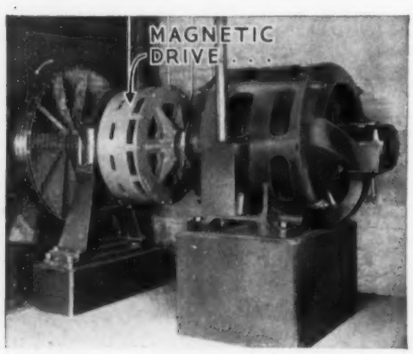
▲ A new variable-speed drive method, using electromagnetic principles for torque transmission, has been developed by Electric Machinery Manufacturing Company. The "magnetic drive" is a rotating device to provide controllable, variable speed. It is placed between a constant-speed driving motor and the load requiring variable speed. Speed is controlled by merely turning a small control-current rheostat knob. This new drive is particularly suited to boiler draft fans which require an accurately controllable wide range of variable speed, and to centrifugal pumps.

The magnetic drive consists of two simple, compact rotating parts, a flux linkage ring, or "ring," and a magnetic flux producer, or "magnet." The ring is driven by the driving motor. The magnet revolves within the ring and drives the load shaft. There is no mechanical torque connection between ring and magnet. The torque is transmitted by electromagnetic forces only, through an air-gap which separates ring and magnet. The torque transmitted by the magnetic drive, and hence the speed of the load shaft, is dependent on the magnetic flux in the air-gap. This magnetic flux is varied by adjusting with a rheostat, the small control current to the magnet.

The magnetic drive requires, in the overhung type, little more overall length than that taken by a standard flange coupling. No accessory equipment is needed for it other than a small source of d-c. control current, and the control current rheostat. The magnetic drive can be applied to new or existing installations, and is available in a wide range of horsepowers and speeds.

Operation of the magnetic drive is on the "slip-loss" principle, which is characteristic of any slip-type torque transmitter.

The slip loss in the magnetic drive, in per cent of the motor input, is proportional to the slip, or difference in speed between ring and magnet.



FARREL ROLL CALIPERS

CHECK ROLL ACCURACY

The Quickest and Most Accurate Way

Uniformity of gauge of rolled strip and sheet depends upon the precision with which the rolls are ground. Accuracy of roll shape can be most easily checked with a Farrel Roll Caliper, an indispensable instrument wherever roll accuracy affects the quality of the product.

The Farrel Caliper measures the variations in roll diameter and the amount of crown, concavity or taper. With it, roll accuracy can be checked against predetermined standards quicker than in any other way, and to a finer degree of accuracy. Readings may be taken at any point along the face of the roll.

The Caliper is simply constructed, light of weight, easy to handle, and is designed for permanent accuracy. It moves freely on rollers, requiring only a finger touch to traverse it along the roll.

Five sizes are available to measure rolls from 4″ to 50″ in diameter. Special sizes made to order.

The use of the Farrel Roll Caliper is fully explained in our new Bulletin No. 112 just issued. This bulletin will be of interest to operating men who desire to avoid the losses caused by imperfect rolls. A complimentary copy will be sent on request.

WRITE FOR COMPLIMENTARY COPY OF BULLETIN NO. 112

FARREL

FARREL-BIRMINGHAM COMPANY, Inc.
ANSONIA, CONN.
New York • Buffalo • Pittsburgh • Akron • Chicago • Los Angeles

ITEMS OF INTEREST

B. H. Gedge, manager of operations, Cleveland district, American Steel and Wire Company, has been appointed assistant to the vice-president in charge of operations. Except for a short period in the West, Mr. Gedge has spent his entire business career with the American Steel and Wire Company in Cleveland. Starting as an electrician at the Cuyahoga Works in 1911, he advanced through various positions, becoming superintendent at Cuyahoga in 1935, and manager of operations, Cleveland district, in 1937.

F. W. Lorig has been named engineer for appropriations and properties, American Steel and Wire Company, Cleveland, Ohio. Until his present appointment Mr. Lorig was construction engineer, having been with the company since 1915.

Mr. Lorig served as chairman of the Cleveland district section of the Association of Iron and Steel Engineers for the 1938-1939 season, and recently was elected to the Board of Directors of the Association.

A. J. Hoyt has been appointed manager of operations in the Cleveland district, for the American Steel and Wire Company. Mr. Hoyt joined the wire company in 1914 as assistant foreman at the Trenton, New Jersey, plant, and subsequently became assistant manager of Worcester, Massachusetts, operations, holding this position until his present appointment.

A. G. Montgomery, superintendent of hot mills, Cuyahoga Works, American Steel and Wire Company, Cleveland, Ohio, has been appointed assistant chief engineer for the company. Mr. Montgomery joined the wire company in 1914, as a district engineer, and since that time has held a variety of engineering positions.

W. V. Magee has become construction engineer of the American Steel and Wire Company, Cleveland, Ohio, succeeding F. W. Lorig. Mr. Magee, who was heretofore assistant construction engineer, joined the company in 1927.

F. E. Robinson was named assistant construction engineer for the American Steel and Wire Company, Cleveland, Ohio. Mr. Robinson, who has been with the company for ten years, was formerly section head draftsman.

American Steel and Wire Company announces the following changes at Worcester, Massachusetts:

Peter Stewart becomes assistant manager of operations in the Worcester district;

G. A. Gleason has been named general superintendent of the South Works;

L. J. Westhaver has become superintendent of the steelworks at the South Works; and

F. P. Leahey becomes superintendent of the wire mill at the South Works.

H. B. Carpenter, manager of the Cleveland district of Republic Steel Corporation, has been appointed assistant vice-president in charge of operations. Mr. Carpenter was born in Pittsburgh, where he attended high school, and was graduated from the University of Michigan in 1906, as a chemical engineer. He was then successively employed in the metallurgical and open hearth departments of Carnegie Steel Company in Pittsburgh; the open hearth department of Jones and Laughlin Steel Corporation, in Pittsburgh; the blast furnace department of the Pittsburgh Crucible Steel Company in Pittsburgh; and the coke oven department of the Cambria Steel Company in Johnstown, Pennsylvania.

In 1916 Mr. Carpenter entered the Colorado Fuel and Iron Company, Pueblo, Colorado, where he became assistant to the vice-president and later manager of the plant. In 1928, he joined the Republic Iron and Steel Company as manager of the Youngstown district, remaining in that capacity with the formation of Republic

B. H. GEDGE

F. W. LORIG

H. B. CARPENTER

Steel Corporation in 1930. In 1935 he was made manager of Republic's Cleveland district.

J. L. Hyland, formerly manager of Republic Steel Corporation's Chicago district, has been appointed manager of the Cleveland district, succeeding H. B. Carpenter. Mr. Hyland was born in Belvidere, Illinois, attended public schools in Rockford, completed his education as a chemist with a correspondence school, and started in the steel industry as a chemist in 1906. In 1915 he became chief chemist at the Illinois Steel Corporation, in Gary, now the Carnegie-Illinois Steel Corporation, and from 1920 to 1930 was superintendent of steel production for the same company. Upon the formation of Republic Steel Corporation, in 1930, he was made district manager of the Chicago district.

C. A. Boughner was appointed director of safety, sheet and tin mills, Carnegie-Illinois Steel Corporation, Gary, Indiana. Mr. Boughner, whose service at the sheet and tin mills began in 1935, was formerly general foreman of the continuous pickler.

W. P. Jones has become assistant superintendent of industrial relations, at the Carnegie-Illinois Steel Corporation's sheet and tin division, Gary, Indiana. Mr. Jones, heretofore industrial engineer, was first employed at the sheet and tin mills in 1936.

R. A. Critten has been appointed general foreman of the continuous pickler, Carnegie-Illinois Steel Corporation, sheet and tin division, Gary, Indiana. Mr. Critten began as a clerk at the 42-in. hot strip mill in 1933. The past two years he has been assistant superintendent of industrial relations.

Tennessee Coal, Iron and Railroad Company, Birmingham, Alabama, has announced the following changes:

G. M. Harris, superintendent of the blast furnaces, Ensley Works, has been promoted to assistant general superintendent;

W. D. Harris, assistant superintendent of blast furnaces at the Fairfield Works, becomes superintendent of those furnaces;

J. A. Maxwell has been elevated from assistant superintendent of blast furnaces to superintendent of the furnaces at the Ensley Works;

J. J. Shannon, turn foreman in the cold reduction department of the Fairfield tin mill, succeeds W. D. Harris as assistant superintendent of the blast furnaces at Fairfield Works; and

John R. Hunt, practice man at the Ensley blast furnaces, succeeds J. A. Maxwell as assistant superintendent there.

A. H. Lauer has been appointed assistant works manager for American Steel Foundries located at the Granite City, Illinois, plant. Mr. Lauer until this appointment has held the position of works engineer at this plant.

J. Morrison was appointed works engineer, succeeding A. H. Lauer, at the Granite City, Illinois, plant of American Steel Foundries.

REGISTERS DRAFT, PRESSURE AND DIFFERENTIAL
in
SOAKING PITS
ANNEALING FURNACES
OPEN HEARTHS
SLAB MILLS
HAYS "OT" DRAFT RECORDER
Results in a better product because it gives a correct indication of furnace atmospheres. Built husky enough to stand the severest steel mill conditions yet sensitive enough to register accurately in increments of .0025 in. water. Employs the famous Hays Slack Leather Diaphragm—self sealing—not damaged under sudden excess pressures. Two draft values, two pressure values, two differential values, or a combination of any two of these three values may be recorded. Or a temperature recorder may be substituted for one of these values. Send for descriptive literature. Write to 955 Eighth Avenue, Michigan City, Indiana.
The HAYS CORPORATION
SINCE 1907
COMBUSTION INSTRUMENTS AND CONTROL
MICHIGAN CITY, INDIANA, U.S.A.

Schloemann Installations in a plate mill at Pittsburgh

Left—"Motor-Roller" equipped Scale Table

Below—
"Motor-Roller" equipped Shear Depressing Table

EXCLUSIVE ADVANTAGES

of

SCHLOEMANN

"MOTOR-ROLLERS"

With the rotating trunnion-type roller housing the driving motor, the necessity for using line shafts, couplings and gear reduction units is eliminated. Simplified table construction is the result, affording free access along both sides of "Motor-Roller" Tables.

Installation of rollers between the housings of Mill Stands and Shear Housings is possible without introducing complicated or weak elements.

Fewer wearing parts provide the ruggedness and dependability essential in mill service with reduced operating and maintenance costs.

Each "Motor-Roller" installation is designed and built for the particular requirements of its application.

SCHLOEMANN

ENGINEERING CORP.
Rolling Mill Machinery

PITTSBURGH, PA.
Hydraulic Presses

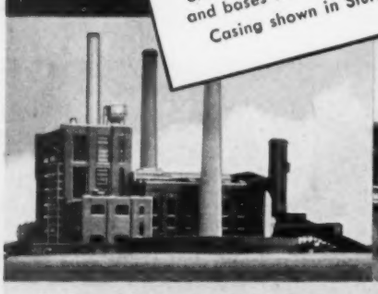
POWER PLANTS

WORLD'S LARGEST HEAVY-DUTY INDUCED DRAFT FAN

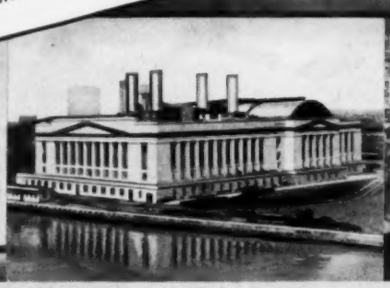
Now installed in Burlington Generating Station, Public Service Electric and Gas Company, New Jersey, this Sturtevant Vane Controlled Mechanical Draft Fan handles 335,000 cfm., 460° F., 13 inches pressure.

Fan wheel weighs over 2½ tons—is nearly 9 ft. in dia. Shaft—16 in. dia.; 23 ft. long. Casing—22 ft. high. Fan and bases weigh 80,000 lbs.

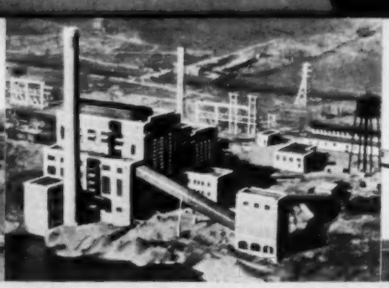
Casing shown in Sturtevant shop before shipment.



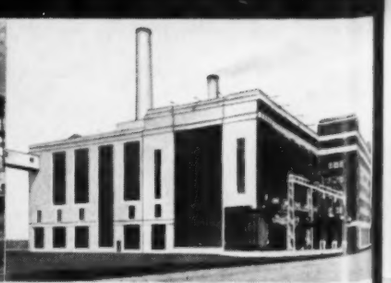
Burlington Generating Station, Public Service Electric and Gas Co., N.J., served by Sturtevant Forced, Induced Draft Vane Controlled Fans.



Richmond Station, Philadelphia Electric Company—18 Sturtevant fans for induced draft, forced draft, primary air, and pulverized coal mill service.



Gilbert Station, New Jersey Power & Light Company, Milford, N. J.—equipped with Sturtevant Forced and Induced Draft Vane Controlled Fans.



Deepwater (N. J.) Station, jointly owned by a subsidiary of Philadelphia Electric Co. and Atlantic City Electric Co., equipped with 12 Sturtevant Forced and Induced Draft Vane Controlled Fans.

along the DELAWARE

served by

STURTEVANT MECHANICAL DRAFT FANS

STURTEVANT mechanical draft installations are meeting the exacting requirements of outstanding plants along the Delaware River.

The reason? High efficiency — ability to stand up under high speeds, high temperatures, high pressures, or large volumes — or the instant response to varying load demands which Sturtevant Patented* Vane Control can assure. No matter what your mechanical draft needs, Sturtevant can fully satisfy them.

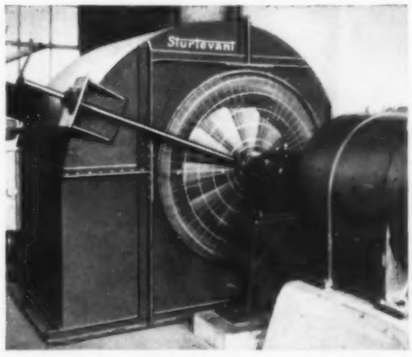
Proof? You will find it in the service records of hundreds of Sturtevant installations — in a *large majority* of the country's public service power plants!

*United States Patent Nos. 1,460,428; 1,578,843; 1,846,863; 1,989,413

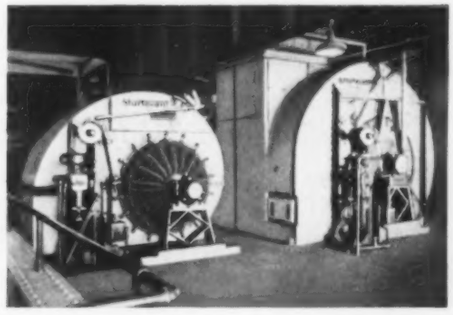
Sturtevant Induced Draft Fans serving 600,000 lb. per hour pulverized-coal-fired boilers for 225,000 hp. turbine in Richmond Station, Philadelphia Electric Company, Philadelphia, Pa.

B. F. STURTEVANT COMPANY
Hyde Park Boston, Mass.
Branches in 40 Principal Cities
B. F. Sturtevant Company of Canada Ltd.
Galt, Toronto, Montreal

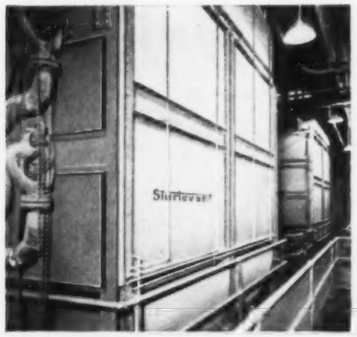
(Licensees of both the Allardice and Buell-Van Tongeren Systems of Dust Collection.)



At right:—This Sturtevant Forced Draft Vane Controlled Fan is one of four Sturtevant Forced and Induced Draft Fans serving the 120,000 lb. steam per hour boilers in plant of RCA Manufacturing Company, Inc., Camden, N. J.



Part of a battery of 12 Sturtevant Vane Controlled Mechanical Draft Fans serving six 1200 lb. boilers for the past 10 years—in Deepwater (N. J.) Station jointly owned by a subsidiary of Philadelphia Electric Co. and Atlantic City Electric Co.



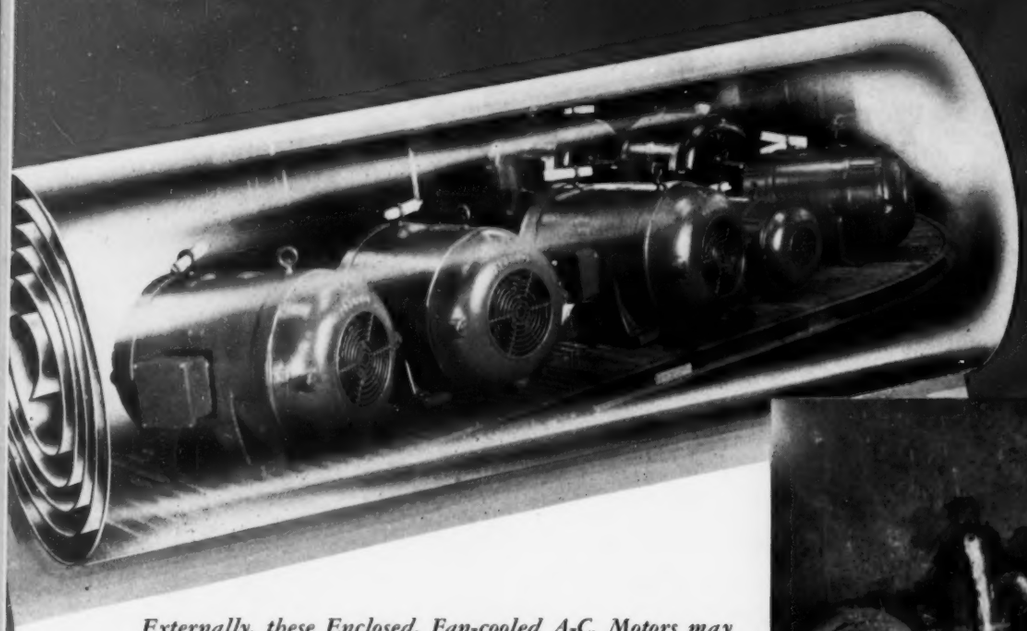
Part of five Sturtevant Extended Surface Steel Economizers at plant of Franklin Sugar Refining Co., Philadelphia, Pa. Each capable of handling at 200% boiler rating, 69,300 lbs. of water per hour, heating it from 210° to 282°F.

One of the Sturtevant Forced Draft Vane Controlled Fans serving 1350 lb. boilers, Gilbert Station, New Jersey Power & Light Co., Milford, N. J.

Sturtevant
REG. U. S. PAT. OFF.
Puts Air to Work

DRAFT FANS • TURBINES • GEARS • ECONOMIZERS • AIR HEATERS

On their Way to Save Money on jobs like *these!*



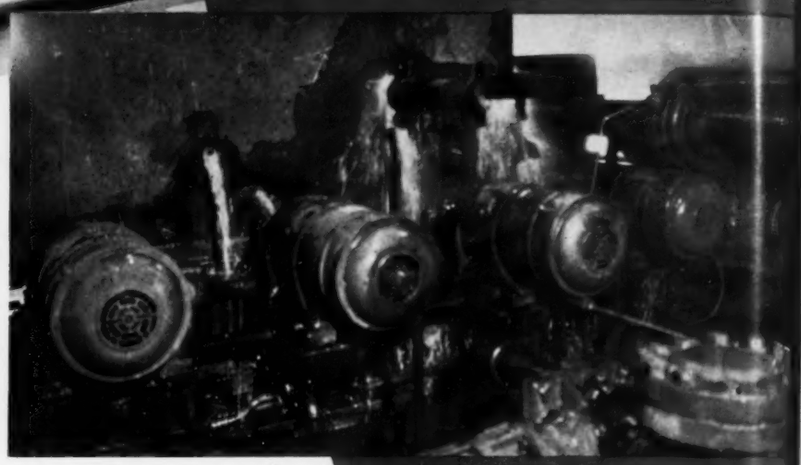
Externally, these Enclosed, Fan-cooled A-C. Motors may lose some of their shine after landing on a steel-mill job, but internally, they will stay clean and dry.

Steel mills are saving money with enclosed, fan-cooled Reliance Motors because they strike at the root of most motor troubles by keeping iron dust, scale, moisture, and oil away from windings and out of air gaps They require less attention and help keep production moving at a steady pace. The extra first cost is cheap insurance against lost tonnage.

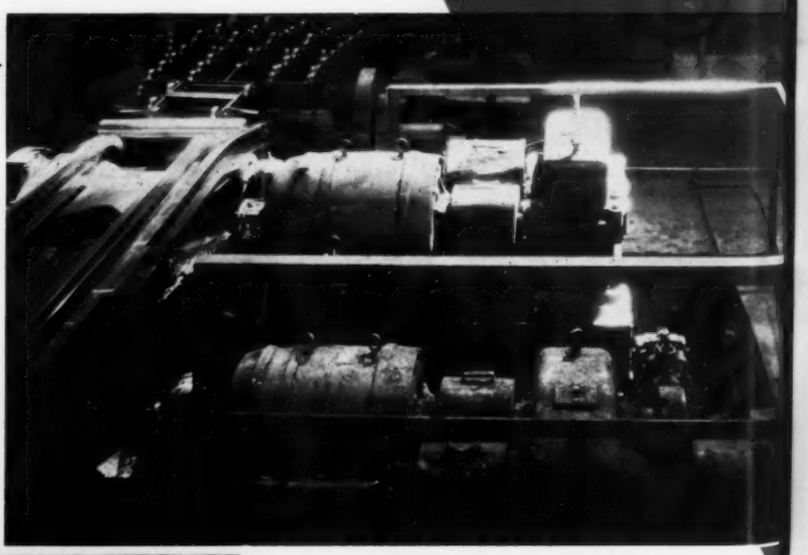
In every country boasting a modern sheet mill you will find Enclosed, Fan-cooled Reliance Motors on automatic feeder-table drives like this. Not a clean spot, and it's hot (asbestos-covered or glass-covered wire is used for the stator windings).

• • •

Bulletins Nos. 120, 121 show how these motors are built to keep windings clean and dry.



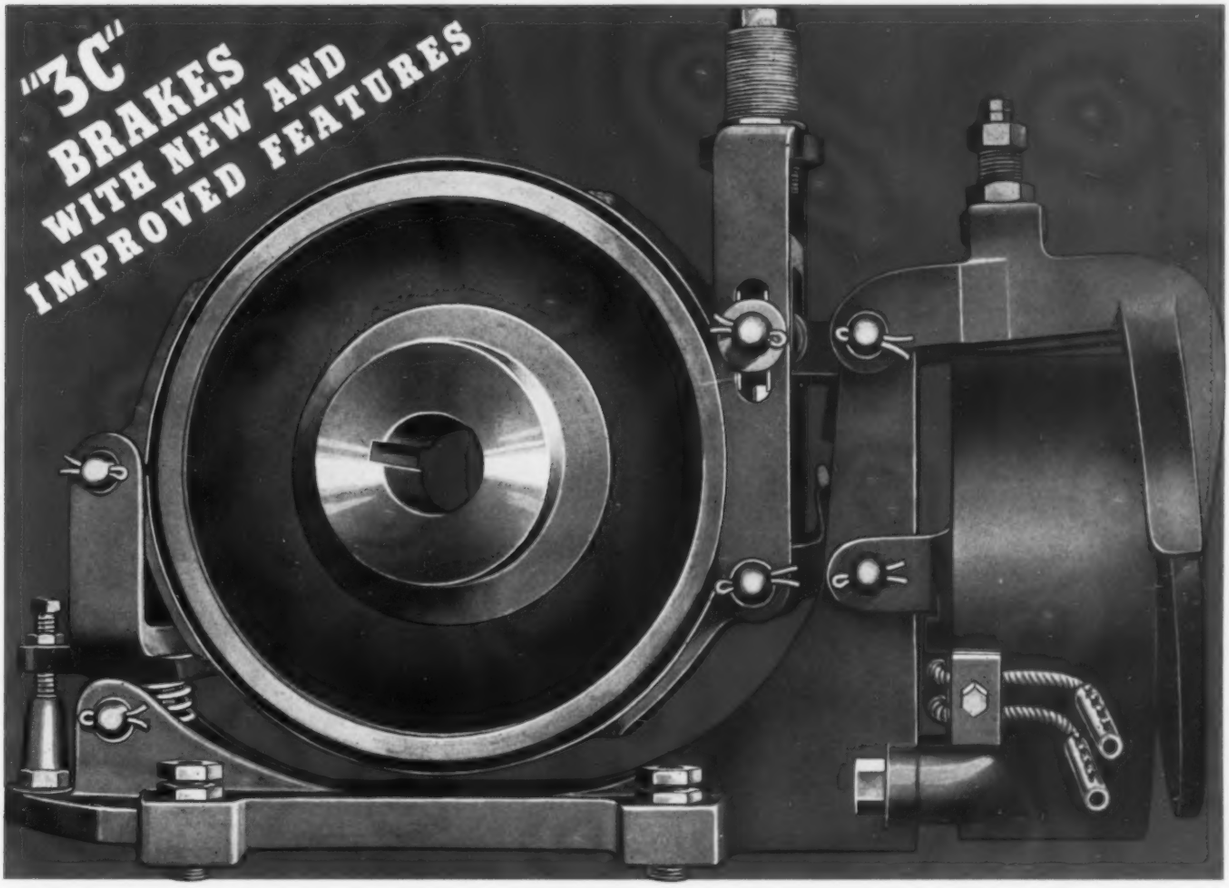
Flying scale and water splashing from the mill sprays make things a bit mussy between the stands of a hot strip mill. But it's a good place to find out whether Reliance Fan-cooled Motors are as good as we say.



RELIANCE ELECTRIC & ENGINEERING CO.
1087 Ivanhoe Road Cleveland, Ohio

RELIANCE A-C D-C MOTORS

Birmingham, Boston, Buffalo, Chicago, Cincinnati, Detroit, Greenville (S. C.), Los Angeles, New York, Philadelphia, Pittsburgh, Portland (Ore.), St. Louis, San Francisco, Syracuse (N. Y.) and other principal cities.



Always sturdy and powerful so as to stand up under the "slam-bang" of industrial operation, "3C" Brakes have new and improved features.

1 The Braking Area on "3C" Brakes is approximately 90% of the wheel surface.

2 With this large Braking Area, longer lining and wheel wear are obtained, because retarding action is obtained with the lowest unit pressure per square inch of Braking Surface.

3 Even wrapping Brake Band action makes "setting" very smooth, and eliminates the "hammer blow."

4 The duplicate Split Bands practically enclose the entire wheel surface, thus eliminating ice or abrasive deposits on the wheel.

5 Brake Band and Shoes are riveted and brazed into one unit, thus distributing stress in operation, so that Band breakage is practically eliminated.

6 Tail Yoke adjustment is easily made without use of special wrenches.

7 Cast Steel Outer Yoke Slots are equipped with easily renewable yoke liners.

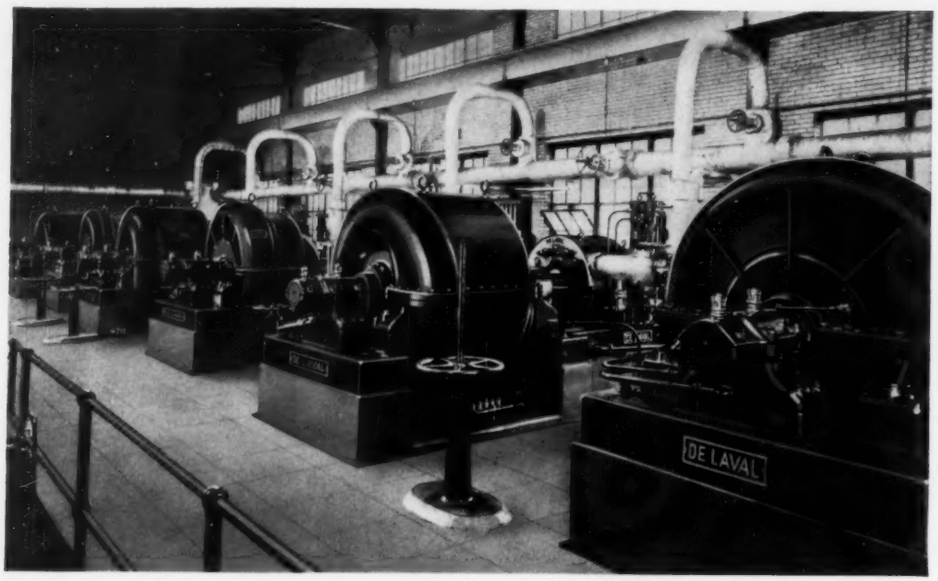
8 New style Mounting Feet, with non-corroding Brass Locking Nut on Bronze Mounting Bushing, provide a broad bearing surface with non-rocking installation and operation.

A folder, fully descriptive of "3C" Brakes is yours for the asking.

CONTINUE TO ROLL WITH CLARK CONTROL

THE CLARK CONTROLLER CO.

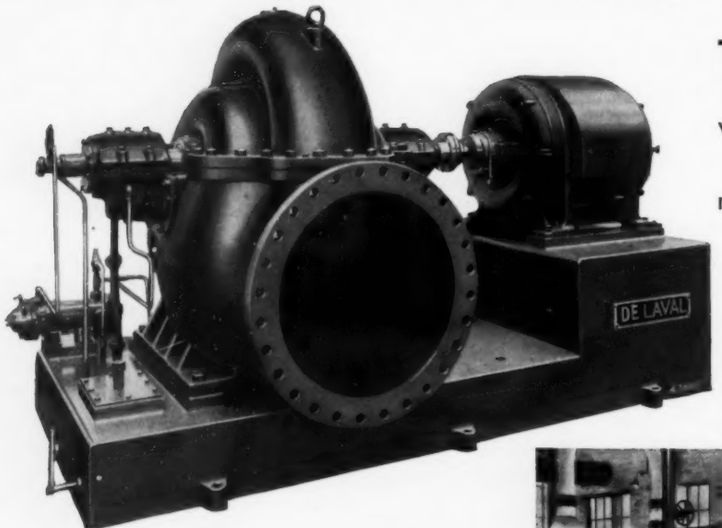
1146 EAST 152ND ST. CLEVELAND, OHIO



Six turbine-driven exhausters and boosters in a coke oven plant. Three machines are three-stage exhausters having a maximum rating of 31,365 cu. ft. per min. each of 0.4 sp. gr. gas at 110° F. against 4.36 lb. total pressure at 3400 r.p.m.; suction pressure minus 10 in. water column. Two of the remaining three are boosters rated at 18,600 cu. ft. per min. each of 0.4 sp. gr. gas at 110° F. against 2.7 lb.; while the third is rated at 25,200 cu. ft. per min. against 5.71 lb.

DE LAVAL BLOWERS, COMPRESSORS AND EXHAUSTERS

Simplify Handling of Air or Gas

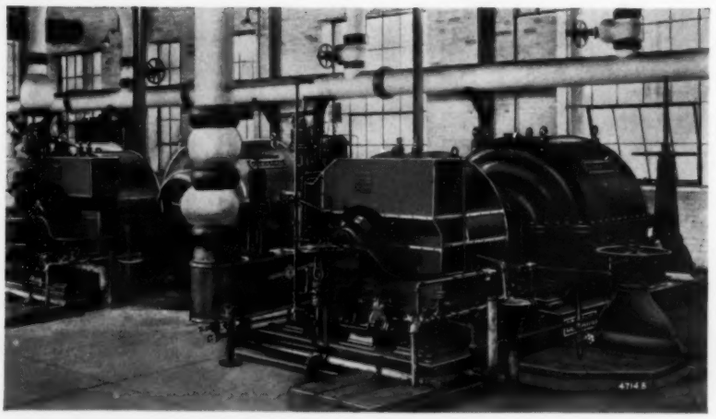


Single-stage, double suction blower; 26,200 cu. ft. per min. of free air against 54 in. water column.

THEY respond quickly to fluctuations in operating conditions and are easily maintained, with minimum upkeep cost.

Describe your air or gas handling requirements so that our engineers can recommend the most suitable equipment. Ask for new Catalog F.

DE LAVAL STEAM TURBINE CO.
TRENTON, NEW JERSEY

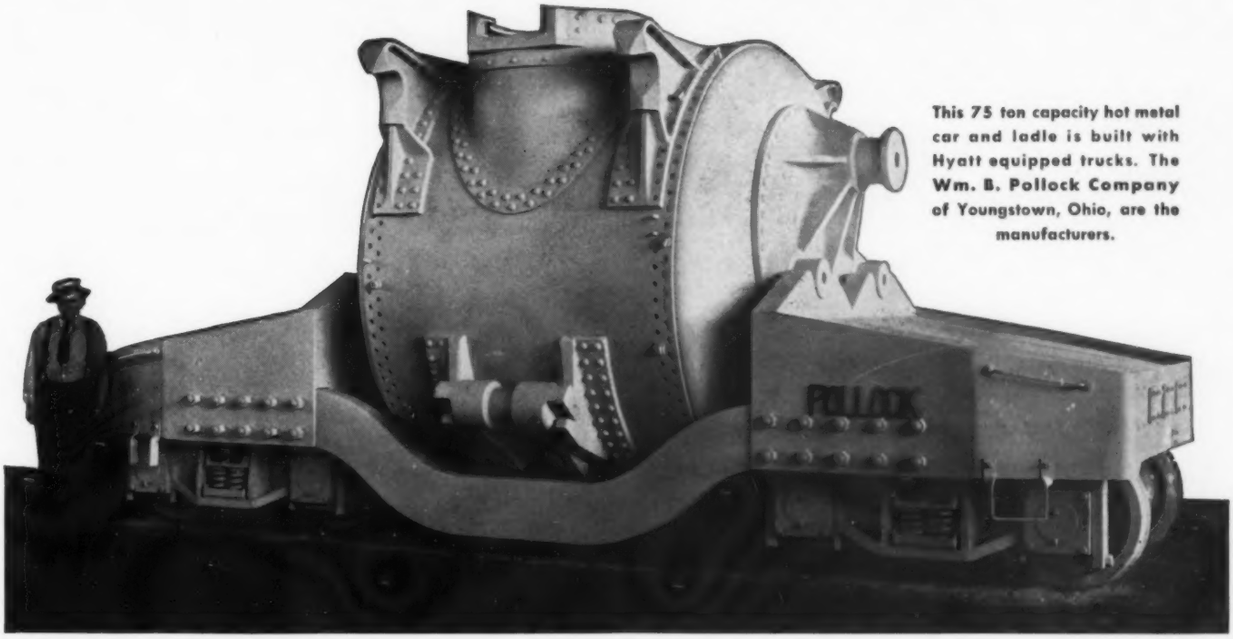


Two four-stage gas boosters in a city gas plant; 16,700 cu. ft. per min. each of 0.62 sp. gr. gas at 60° F. against 10 lb. pressure at 4000 r.p.m. The multi-stage turbines exhaust to the process at 10 lb. back pressure.

3813

Hyatt Mettle for Hot Metal

...or any other tough job!



This 75 ton capacity hot metal car and ladle is built with Hyatt equipped trucks. The Wm. B. Pollock Company of Youngstown, Ohio, are the manufacturers.

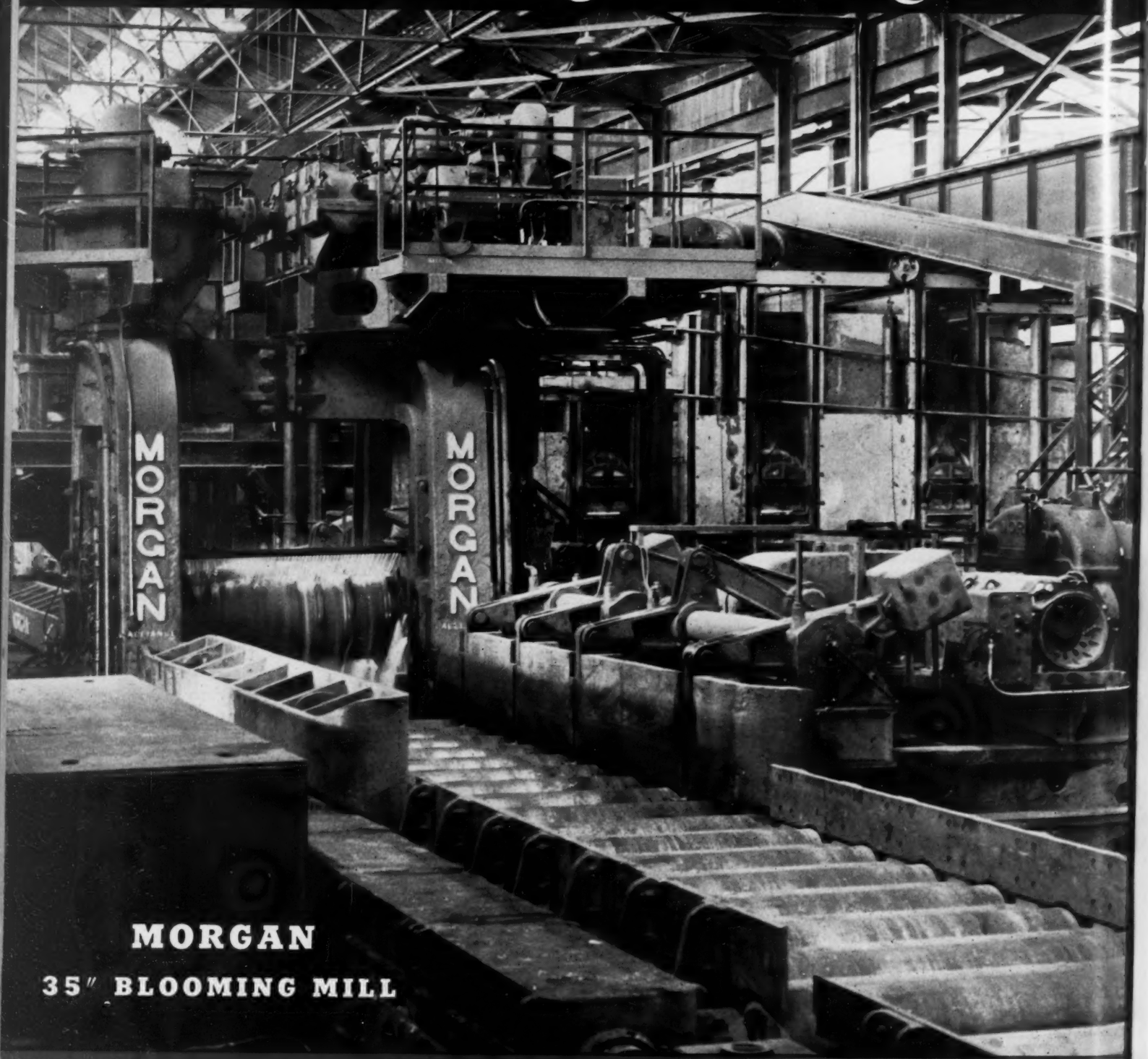
To stand up under the punishing shocks and heat of metal car service, bearings that carry the load are surely put on their mettle. Yet Hyatt Roller Bearings in applications like this, and every other tough job in the mill, are equal to the task.

Tables, cranes, motors, and all other auxiliary mill equipment, along with all kinds of cars, are made better performing, longer lived, and more carefree when Hyatt equipped.

Let us show you how well and how long Hyatts can serve on any of your new mill equipment or changeovers. Hyatt Bearings Division, General Motors Sales Corporation, Harrison, N. J., Chicago, Detroit, Pittsburgh, San Francisco.

HYATT *Roller* BEARINGS

BUILT BY MORGAN *Engineering*



MORGAN
35″ BLOOMING MILL

● Above is shown a Morgan 35″ two-high blooming mill complete with double manipulator, front and rear tables. Two mills of this type were recently furnished prominent mid-west steel producers. Housings are one-piece steel castings of the closed top type. Top roll balance is of the counterweight type.

Manipulator is of the overhead type, compact and accessible. Tables are of heavy design, equipped with anti-friction bearings. Screw-down drive is arranged to provide crane hook access when changing guides. Provision is made for automatic lubrication and exclusion of scale and dirt.

★ DESIGNERS • MANUFACTURERS • CONTRACTORS
BLOOMING MILLS • PLATE MILLS • STRUCTURAL MILLS
★ ELECTRIC TRAVELING CRANES • CHARGING MACHINES
INGOT STRIPPING MACHINES • SOAKING PIT CRANES
★ ELECTRIC WELDED FABRICATION • LADLE CRANES
STEAM HAMMERS • STEAM HYDRAULIC FORGING
★ PRESSES • SPECIAL MACHINERY FOR STEEL MILLS
THE MORGAN ENGINEERING CO., Alliance, Ohio
★ Pittsburgh, 1420 Oliver Building

PYLE-NATIONAL
HIGH EFFICIENCY FLOODLIGHTING
solves lighting problems

Yards, driveways, platforms, and many other mill locations difficult to light by ordinary means are easily and economically lighted with Pyle-National floodlighting units. This equipment provides ample working light uniformly distributed, yet fewer units are required, simplifying installation and control.

Pyle-National floodlights have the substantial, corrosion-proof construction necessary for heavy-duty service. Weathertight design reduces cleaning and other maintenance, and protects the projector interiors. Correct reflector design and controlled light distribution delivers maximum illumination with minimum current consumption.

Pyle-National floodlighting equipment is available in a complete line of standard types from 100 watt to 5000 watt size, including portable units, narrow beam floodlights, pit lights, and utility floodlights, meeting the varied requirements of mill lighting.

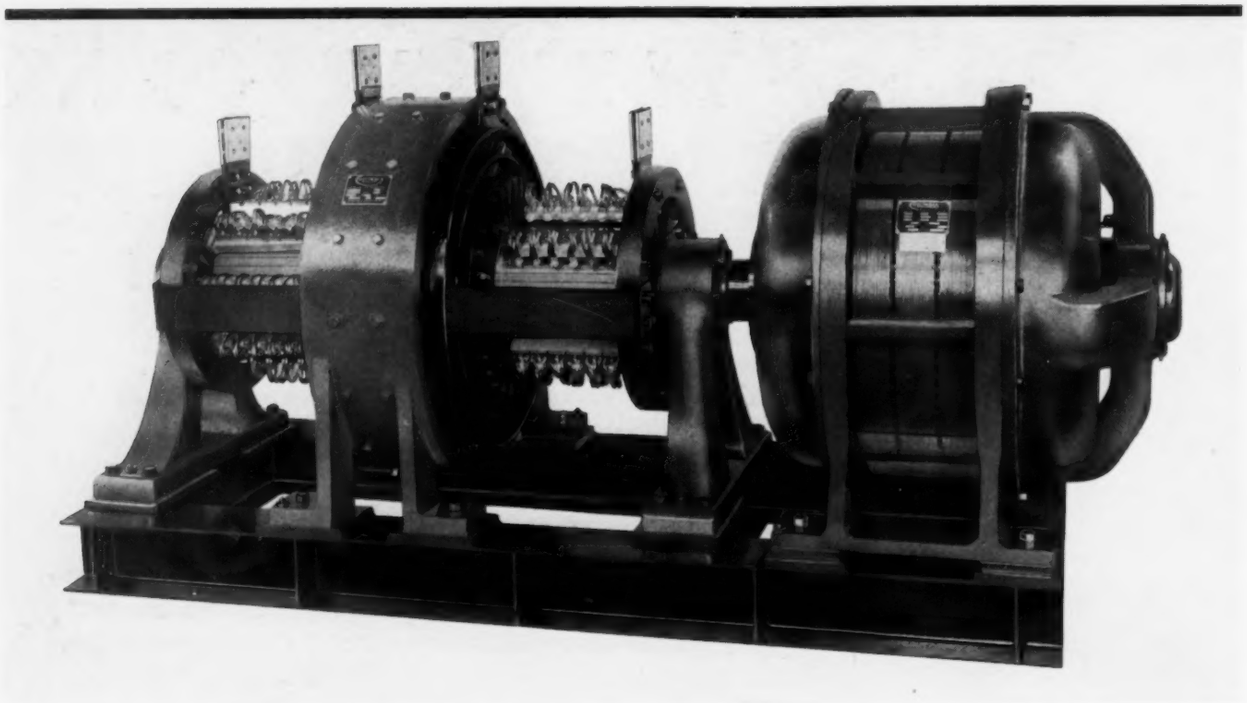
Catalog No. 211 giving full information on all types, with beam efficiency, candlepower, and light distribution data, will be sent upon request.

Pyle-National floodlights available in sizes from 100 watts to 5000 watts.

PYLE-NATIONAL

The Pyle-National Company, *General Offices and Works,* 1334-58 Nor[illegible] Kostner Avenue, Chicago, Illinois • *Offices:* New York, Baltimor[illegible] Pittsburgh, St. Louis, St. Paul, San Francisco.

CONDUIT FITTINGS • LOCOMOTIVE ELECTRICAL EQUIPMENT • FLOODLIGHT PROJECTORS



5,000 ampere, 6 volt, 600 R. P. M. 3 bearing Columbia synchronous motor-generator set.

"STEEL MILL TESTED" MOTOR GENERATOR SETS

FOR CONTINUOUS ELECTRO-PLATING AND ELECTRO-CLEANING

The continuous electro-plating, pickling and cleaning of strip or sheet steel depends entirely on a reliable source of high ampere, low voltage current. With this fact as a guide, Columbia engineers have developed a line of generators which perfectly meet the rigid requirements of this service.

To know the construction details of Columbia generators is to understand their unfailing, dependable performance. Among the many important features which they embody are: butt-welded steel frames; sparkless commutation from no load to 200 per cent load resulting in long brush life; roller bearings.

Columbia generators and motor-generator sets are built in a complete range of sizes; ½ to 250 KW, 100 to 40,000 amperes, 6 to 60 volts. The coupon below will bring you complete facts about these Columbia better-built generators. Mail it, today.

COLUMBIA

COLUMBIA ELECTRIC MFG. CO.
4505 HAMILTON AVENUE CLEVELAND, OHIO

Please send me a copy of Bulletin 700 describing Columbia Generators and Motor Generator Sets.

Individual .....

Company .....

Address .....

City and State .....

LOW VOLTAGE GENERATORS AND MOTOR GENERATOR SETS

GENERAL MANAGER: I see you insist on Fast's Couplings, Bill. Why is that?
MAINTENANCE ENGINEER: Because I'm held responsible for continuous operation . . . and I know I can depend on Fast's.
CHIEF ENGINEER: Bill is right . . . our records show it. With your permission we'll specify Fast's throughout.

STEEL ENGINEERS KNOW THE RIGHT ANSWERS

Alert operating men are avoiding troubles by anticipating them. Since Fast's Self-Aligning Couplings were put on the market, thousands of them have been installed on main rolls and auxiliary drives where they have made an enviable place in steel mill history for dependable, trouble-free operation.

These qualities are built into Fast's Couplings. The only attention they require is oiling. The sectional view at right shows the exclusive features that assure dependability.

Specify *genuine* Fast's Self-Aligning Couplings on all machinery you purchase and avoid operating trouble.

KOPPERS COMPANY
BARTLETT HAYWARD DIVISION
BALTIMORE, MD.

This sectional view shows Fast's construction. The load carrying surfaces are protected against wear by a positive film of oil. This oil is kept permanently clean by the rocking bearings which make precise metal-to-metal contact and are in the one position where they form permanent dust and moisture-proof seals. No perishable materials are used. No attention but oiling is required.

● **OTHER KOPPERS PRODUCTS FOR THE STEEL FIELD:** Coal . . . Coke . . . Coal Handling and Preparation Plants and Equipment . . . Coke Oven Plants . . . Gas Holders and Equipment . . . Purification Systems . . . Materials Handling Systems . . . Treated Timber . . . Waterproofing . . . Lumino and Bituminous Base Paints . . . Built-up Roofs . . . D-H-S Bronze . . . American Hammered Piston Rings and Packing . . . Hot Metal Transfer Cars . . . Ships, Barges and Dry-Docking Facilities.

FAST'S SELF-ALIGNING COUPLINGS

use KOPPERS *products*

Enjoy OKONITE QUALITY in your Wires and Cables

Experience has proved that "Okonite Quality" is a tangible quality—an actual difference in the properties of insulation which can be definitely measured in reduced maintenance, continuous freedom from trouble and in years of added service.

This quality is no mere accident because wires and cables made by Okonite are custom built for the job. Okonite's precise manufacturing methods and severe test requirements keep one out of every six of its factory employees engaged in inspection or research.

Wires and cables insulated with Okonite have an unequaled record for long life under steel mill conditions that are certain death to ordinary wire.

THE OKONITE COMPANY

Founded 1878

EXECUTIVE OFFICE:
HAZARD INSULATED WIRE WORKS DIVISION

PASSAIC, NEW JERSEY
THE OKONITE-CALLENDER CABLE CO., INC.

New York Boston Seattle Buffalo Chicago Dallas Detroit Atlanta
Philadelphia Los Angeles Pittsburgh Cleveland St. Louis Washington San Francisco

OKONITE QUALITY CANNOT BE WRITTEN INTO A SPECIFICATION

New CAPACITIES *for* OLD FURNACES

with the modern Isley System

Important increases in capacities of old open hearth furnaces are now possible at relatively low cost. The Isley Furnace System of short venturi stacks, blowers, and compact checkers permits greater fuel and regenerative facilities without extensive alterations to the furnace design. The use of two or three pass checkers is practical with the Isley Furnace System and will supply the additional regenerator capacity to fire efficiently a hearth of greater capacity than your present installation. Better control of combustion is afforded, with real savings in furnace operation and maintenance.

The effectiveness of the modern Isley Furnace System has been proved in many old and new installations and under widely varying conditions. Reliable Morgan engineers will be glad to study *your* furnace problems and submit their carefully considered recommendations.

Write today for the new Isley Bulletin or for details on Morgan engineering service.

MORGAN CONSTRUCTION COMPANY, WORCESTER, MASS.

English Representatives: International Construction Company, 56 Kingsway, W. C. 2, London, England.

MORGAN WORCESTER ENGINEERS AND MANUFACTURERS

V-17

ISLEY Furnace Control System

You can DO THINGS with a BAKER Center Control Fork TRUCK

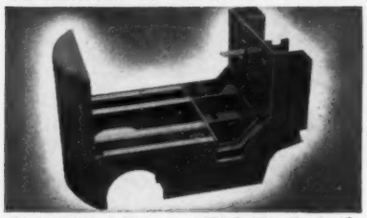
An Important Unit in the BAKER Line of Handling Equipment . . .

● The Baker Center Control Fork Truck with hydraulic lift and tilt sets new standards for speed, safety and efficiency in material handling. Here's why: *Center Control* means better vision, greater compactness and greater safety . . . *Hydraulic Lift* means simplicity, greater hoisting efficiency, faster lifting (20 to 40 FPM) and faster lowering (60 FPM) . . . *Accessibility of all parts* means speedy servicing and easier maintenance.

Let the BAKER Material Handling Engineer show you these and other advantages of the Baker Type JOM Center Control Fork Truck. This model available in 1000 to 7000 lb. capacities, other models to 30,000 lbs.

BAKER INDUSTRIAL TRUCK DIVISION
2166 West 25th Street • Cleveland, Ohio

BAKER ENGINEERING IS YOUR GUARANTEE OF SUPERIOR SERVICE



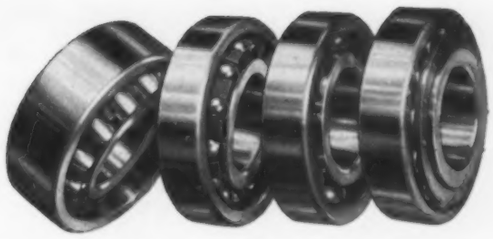
Unit Welded Frame of High Tensile Steel has heavy deep-section sills from axle to axle. Sturdy outside skirt panels protect against collision damage.

Worm drive is most efficient and longest lived. Large models have hydraulic wheel brakes. Baker motors provide best combination of torque and efficiency.

Wide-angle steering axle, for short radius turning. Leaf springing compensates for uneven floors, as well as absorbing shocks.

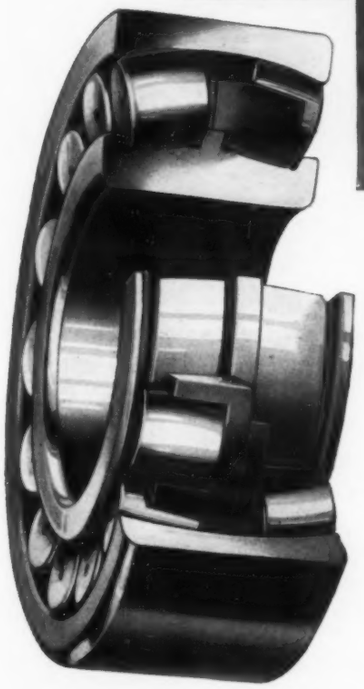
Trade mark Registered U. S. Pat. Off.

Baker POWER INDUSTRIAL TRUCKS FOR EVERY PURPOSE



DRIVES NEED TOUGH BEARINGS FOR 24-HOUR SERVICE IN STEEL MILLS

● *Gear reduction drives built by Farrel-Birmingham Co., Inc.*



FARREL-BIRMINGHAM DRIVES HAVE SKF BEARINGS, AND THAT MEANS RELIABILITY YEAR IN AND YEAR OUT

● When you must drive mills 24 hours a day, month after month, you need bearings that can take heavy loads and never ask for anything more than normal lubrication. You need bearings like the SKF Spherical Roller Bearings on these Farrel-Birmingham drives.

The full capacity of SKF Bearings is always available for useful work. Permanently adjusted, they require no correction for wear. But the one big advantage that makes them stand out on heavy duty equipment of all kinds is their ability to keep shaft centers *every* day this year and for many years to come.

Write for our catalog, "SKF Rolling Mill Data for Calculation and Design", on your business or personal stationery. This valuable catalog will show you many ways to cut costs by using the right bearing in the right place.

4442

SKF

Ball and Roller Bearings

SKF INDUSTRIES, INC., FRONT ST. & ERIE AVE., PHILA., PA.

CROUSE-HINDS
FS and FD Series
General-Use Condulets

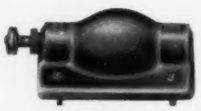
FAR321 Arktite Plug Receptacle Housing

DS32g Guarded Switch Cover

DS10g Spring Door For Plug Receptacle

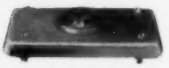
DS108 Vaportight, For Double Push Button Switch

Type FSC Condulet
Shallow Type

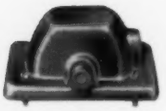


DS128 Vaportight, For Tumbler Switch

DS181 Vaportight For Tumbler Switch



DS24g Pilot Lamp



DS182 Vaportight, For Tumbler Switch

With over one hundred and ninety bodies and more than one hundred different covers available, the FS and FD series Condulets are suitable for many flush wiring devices, such as switches, plug receptacles, small circuit breakers, pilot lamps, etc., and for a variety of locations, including exposure to weather, vapors, and fumes.

These Condulets may be mounted exposed or concealed, as within a wall. Flush and surface covers are available.

There is ample room for the passage of extra conductors around the wiring device.

FD (deep type) is the same as FS (shallow type) except that the body is ⅞ inch deeper.

Both FS and FD types are made in two, three, and four-gang with various hub arrangements. They take two, three, and four-gang covers.

In addition, both FS and FD Condulets are made in multiple gang without hubs. Hubs can be welded in place to meet special requirements. These Condulets have individual cover openings which take any of the single covers. Due to this construction, special combinations of devices may be easily assembled.

All FS and FD Condulets can be furnished with hubs threaded for thick wall conduit or with threadless hubs for thick or thin wall conduit.

Refer to Section 10, Condulet Catalog 2500, for complete listings.

A Nationwide Distribution Through Electrical Wholesalers

Condulet Catalog No. 2500 will be sent on request.

CROUSE-HINDS COMPANY
SYRACUSE, N. Y., U. S. A.

Sales Offices: Atlanta — Birmingham — Boston — Chicago — Cincinnati — Cleveland — Dallas — Detroit — Houston — Kansas City — Los Angeles — Milwaukee — Minneapolis — New York — Philadelphia — Pittsburgh — San Francisco — Seattle — St. Louis — Washington

CH676

CROUSE-HINDS COMPANY OF CANADA, LTD., *Main Office and Plant:* TORONTO, ONT.

"Better than normally expected"

7000-kw. motor-generator set equipped with Speer E-35 Multiflex Brushes driving 3-stand tandem cold-rolled mill.

Steel mills report that SPEER Multiflex Brushes are doing work better than normally expected of good solid brushes. That is what SPEER designed these brushes to do—another example of what can be achieved by over forty years of concentrated research, adequate facilities, distinguished personnel and the will to excel.

If your data on SPEER Multiflex Brushes are incomplete, write for Bulletin No. 50.

SPEER CARBON CO.

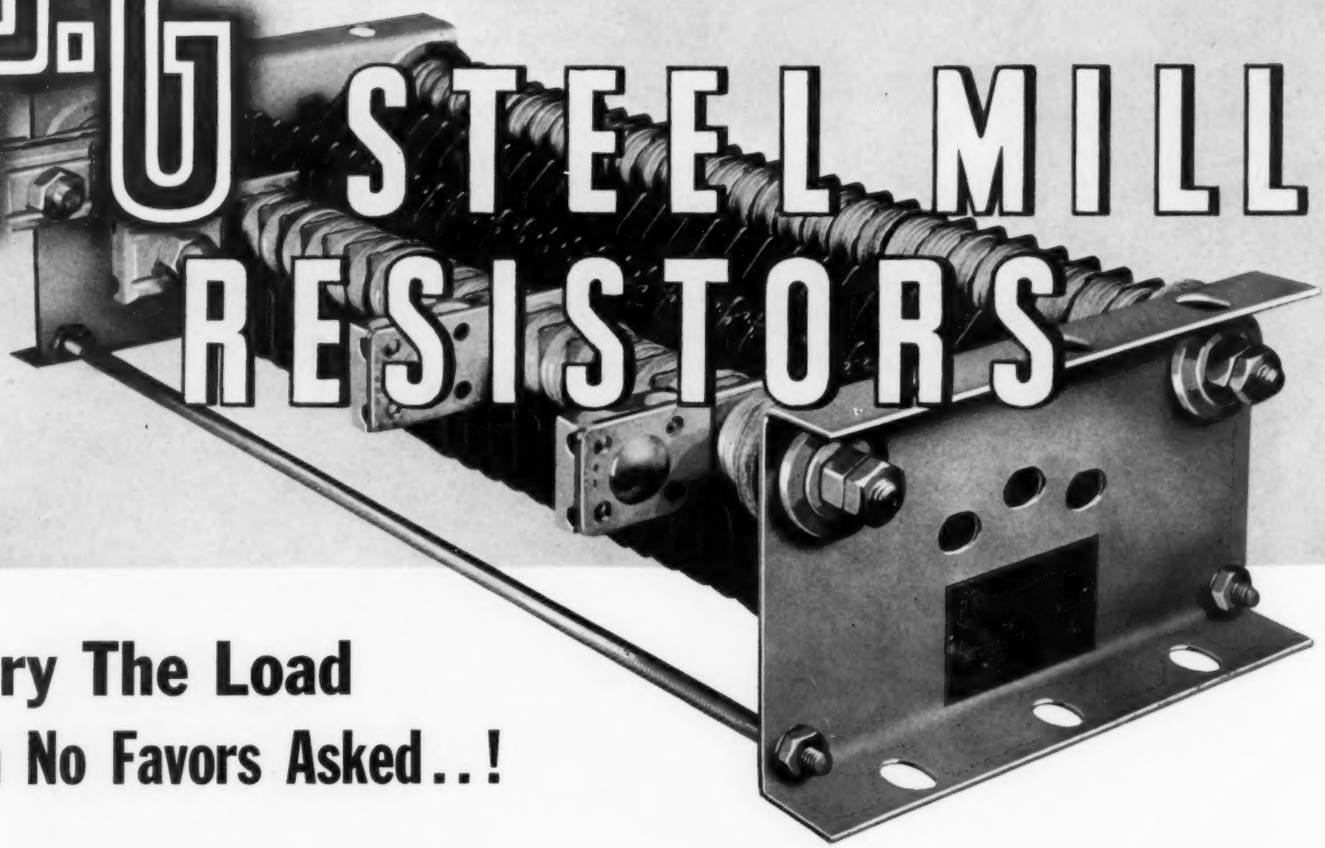
SCC

ST. MARYS, PA.

Chicago Cleveland Detroit Milwaukee New York Pittsburgh

116

P-G STEEL MILL RESISTORS



Carry The Load With No Favors Asked..!

USE P-G *Unbreakable* RESISTORS

for less motor maintenance .. fewer shut-downs
more production .... lower operating costs

P-G STEEL GRID RESISTORS ARE NOT AFFECTED BY VIBRATION, MOISTURE OR CORROSIVE FUMES . . .

THAT'S WHY

More Steel Mill Engineers are using P-G

"The RESISTOR you can INSTALL and FORGET"

P-G

THE POST-GLOVER ELECTRIC COMPANY

• ESTABLISHED 1892 •

221 WEST THIRD STREET, CINCINNATI, OHIO

Electric balancing sensitivity

Another feature of BRISTOL'S WIDE-STRIP PYROMETER *contributing to fine performance*

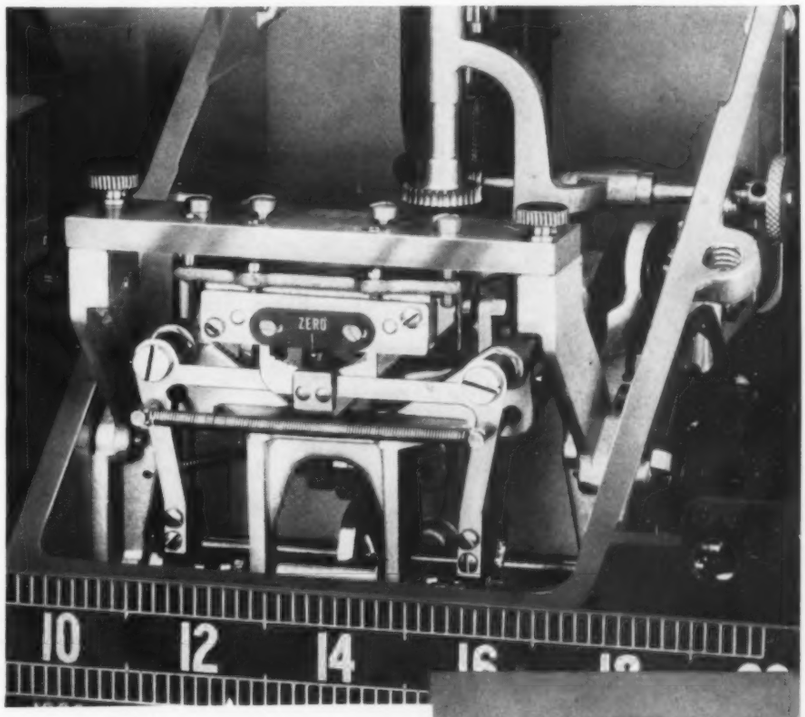
In responsiveness, too, this modern Bristol's Wide Strip Pyrometer will amaze you with its impressive performance. The instant the temperature changes, the galvanometer feels the change. Instantly the galvanometer pointer responds, even to slight temperature fluctuations so minute that the corresponding pointer deflection cannot be detected by the naked eye.

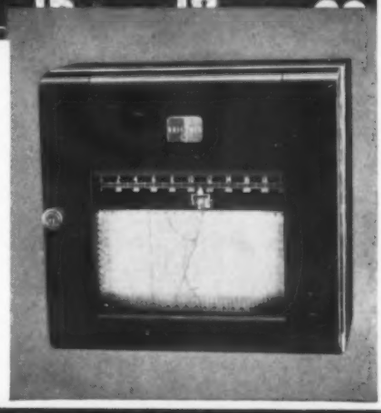
Then, because for such small galvanometer deflections the chopper arms have a contour that is smooth and continuous, corrective action is immediate. It is of *just the right amount* to make possible precisely *accurate control.*

The mechanical backlash in the chopper arms is completely taken up on each periodic movement. No clearance between chopper arms and pointer is required.

Feature after feature! All contributing to fine performance, and accurate temperature measurement and control. That is the story of Bristol's Wide Strip Pyrometer. Write for Catalog 1452H.

THE BRISTOL COMPANY
WATERBURY, CONNECTICUT
Branch Offices in Principal Cities



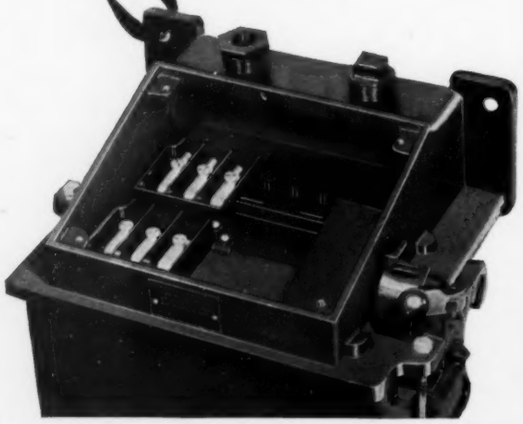


CRAFTSMANSHIP *you can see at a glance!* Reflecting throughout the simplicity, beauty and perfection that identify the genius of the master craftsman, this Bristol's Wide-Strip Pyrometer possesses many other interesting features that you will want to know about. The following will be discussed in subsequent advertisements: (a) Circuit automatically standardized, (b) Electric balancing, (c) No lost motion, (d) Visible operating mechanism, (e) Extra wide 12¼ inch chart, (f) Duplex slide wire accuracy, (g) Large easy to read scale, (h) Automatic cold junction compensator.

BRISTOL'S
TRADE MARK REG. U. S. PAT. OFF.
Wide-strip Pyrometer

RECORDING ★ CONTROLLING ★ MULTIPLE RECORD MODELS

Customers using the 25th Anniversary Design of the 780-KBF across - the - line motor starter have placed the certificate of merit upon it for its sealed-off wiring chamber and other important improvements in oil immersed control equipment. Inquire now for detailed information.



THE ROWAN CONTROLLER CO. 25th ANNIVERSARY 1914-1939 Baltimore, Md.

ROWAN CONTROL

Motor control can be supplied, mounted and ready to wire. Send us your specifications.

ROWAN CONTROL
THE ROWAN CONTROLLER CO., BALTIMORE, MD.

Outer Rings of Ohio Magnets Seldom Break

The bottom or bearing face of an Ohio Magnet presents a smooth long lived surface to the work.

There are no holes or depressions to start wear or cracks.

THIS MEANS LOW MAINTENANCE COST.

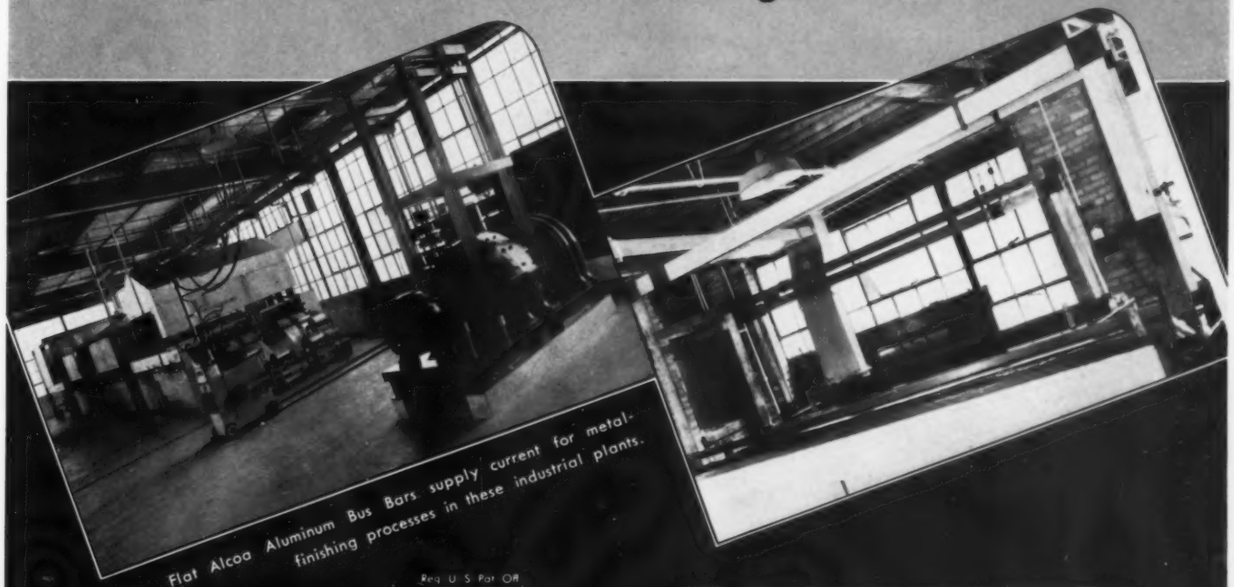
OHIO reliable MAGNETS

THE OHIO ELECTRIC MFG. COMPANY

5907 Maurice Ave. Cleveland, Ohio

INDUSTRIAL PLANTS KNOW VALUE OF LIGHTWEIGHT, CORROSION-RESISTANT

Alcoa Aluminum Bus Bars



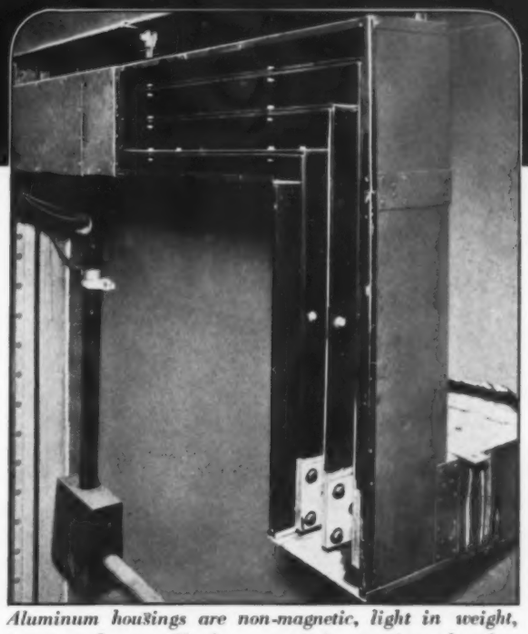
Flat Alcoa Aluminum Bus Bars supply current for metal-finishing processes in these industrial plants.

Reg. U. S. Pat. Off.
ALCOA
ALUMINUM

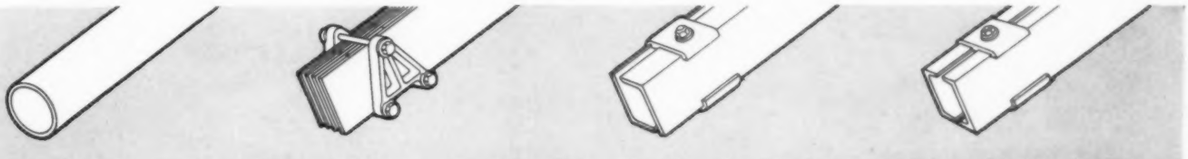
Bus bars are frequently subjected to attack by corrosive gases generated in industrial processes. That's why Alcoa Aluminum bus bars are so widely used to serve these processes. Aluminum performs well under adverse conditions.

The light weight of Aluminum bus bar is an equally important advantage; buses must often be installed where no provision was made for supporting heavier materials. Aluminum provides ample current-carrying capacity and strength to withstand short-circuit stresses.

Ask our engineers for recommendations and a quotation on your next bus bar installation. ALUMINUM COMPANY OF AMERICA, 2128 Gulf Building, Pittsburgh, Pennsylvania.



Aluminum housings are non-magnetic, light in weight, strong and neat. Need no protective coating of paint. Aluminum is easy to fabricate; sheet and structural shapes may be purchased from conveniently located stocks.



ALCOA · ALUMINUM

Dripping, Leaking Oil Means Wasted Dollars

The story of oil shirking its job is being told all over most plants. Oil on floors makes them slippery and dangerous. Not only that—it requires 3 to 5 times the quantity than would be needed if oil stayed in bearings.

To overcome these evils—NON FLUID OIL is used in thousands of plants. Drip-less and waste-less, it stays in bearings until entirely consumed, lasts longer and requires less frequent application; so provides more dependable lubrication at less cost.

Used successfully in leading iron and steel mills. Send for testing sample today—prepaid —NO CHARGE.

•

New York & New Jersey Lubricant Co.

Main Office: 292 Madison Ave., New York, N. Y.

WAREHOUSES:

Chicago, Ill.	Atlanta, Ga.
St. Louis, Mo.	Detroit, Mich.
Providence, R. I.	Greenville, S. C.

TRADE MARK REGISTERED
NON-FLUID OIL
IN U.S. PAT. OFFICE & FOREIGN COUNTRIES

MODERN STEEL MILL LUBRICANT

Better Lubrication at Less Cost per Month

IN TIMES LIKE THESE

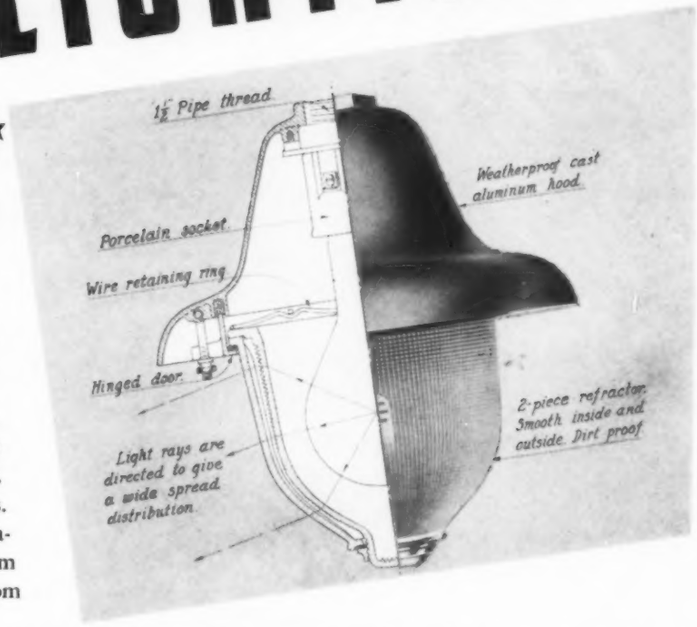
– Industry Safeguards its Properties with

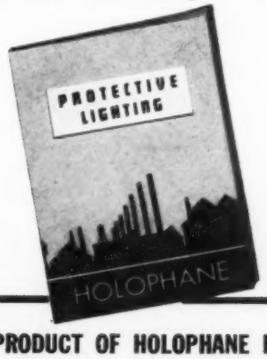
PROTECTIVE LIGHTING

HOLOPHANE REFRACTORS★ provide LOW-COST PROTECTION

(1/10¢ per square foot)

To thwart lawlessness, fire and theft during periods of emergency, plants are installing Holophane Yard Lighting Refractors . . . Specially designed for the use, these units are rugged, dependable and highly efficient for outside night lighting . . . Require no special towers or circuits. Built to withstand the most trying conditions. Trouble-free, dust-proof and resistant to deterioration. Made in sizes to take ordinary lamps from 100 to 500 watts . . . Available immediately from distributors' stocks in your locality.


1½ Pipe thread
Weatherproof cast aluminum hood
Porcelain socket
Wire retaining ring
Hinged door
2-piece refractor. Smooth inside and outside. Dirt proof
Light rays are directed to give a wide spread distribution



WITHOUT CHARGE TO YOU *the Holophane Engineering department will send a comprehensive book on protective lighting. Write for it TODAY . . .*

★ **PRODUCT OF HOLOPHANE RESEARCH**

Holophane

COMPANY, INC. — *Lighting Authorities—Since 1898*

342 MADISON AVE.
NEW YORK CITY

THE HOLOPHANE CO. LTD.
385 Yonge St., Toronto, Canada

New!!

TRICO

UNBREAKABLE GRAVITY FEED OILERS

ULTRA-MODERN

UNBREAKABLE

STREAM-LINED

NO GASKETS TO LEAK

50% LESS WEIGHT

REINFORCED DUAL RATCHET FEED ADJUSTMENT

AMERICA'S FINEST GRAVITY FEED OILER. MODERNIZED AND STREAMLINED TO HARMONIZE WITH ADVANCED IDEAS OF MACHINE DESIGN. 12 DISTINCTIVE FEATURES—METAL PARTS CADMIUM-PLATED FOR BEAUTY AND EASY-CLEANING. 3 STYLES IN ONE. TWO, FOUR AND EIGHT OZ. CAPACITIES.

WRITE FOR BULLETIN No. 26

TRICO FUSE MFG. CO. Milwaukee, Wis.

Let this Trico Combination SAVE YOU MONEY!

FAULTY FUSES and BAD CLIP CONTACT are the cause of thousands of unnecessary shutdowns. TRICO *Powder-Packed* Renewable Fuses and KLIPLOK Clamps will stop this inexcusable waste.

TRICO Powder-Packed FUSES

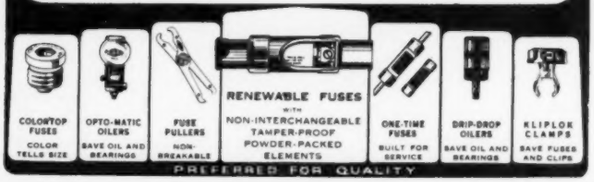
They're different. The *powder-packed* element does away with all the hazards and inefficiencies of "doubling-up" links—over-done time lag—interchangeability, etc. It's loaded with engineering values that guarantee safety and dependable performance beyond comparison. Write for folder No. 206-Y.

KLIPLOK CLAMPS

Eliminate burnt fuses and clips—unnecessary shutdowns and wasted current caused by over-heating. There's a size for every clip. USE KLIPLOKS EVERYWHERE.

TRICO FUSE MFG. CO., MILWAUKEE, WIS., U.S.A.

In Canada—IRVING SMITH, LIMITED—Montreal



You can do a Better DESCALING Job and do it Faster and Cheaper BY WHEELABRATING

Cleaning Steel Strip in a Special WHEELABRATOR Cabinet at the Wallace Barnes Co., Bristol, Connecticut.

The first commercial installation to descale, billets, sheets, rounds, etc. without the use of pickling or compressed air was made in 1933 when the WHEELABRATOR *airless* abrasive blasting process was placed in operation in a large mid-western steel plant.

Since that time WHEELABRATOR has captured a sizable volume of new business in the steel industry.

The reason? Because WHEELABRATOR is less expensive to install—requires less floor space—permits perfect control of the finish—and provides faster, more economical production.

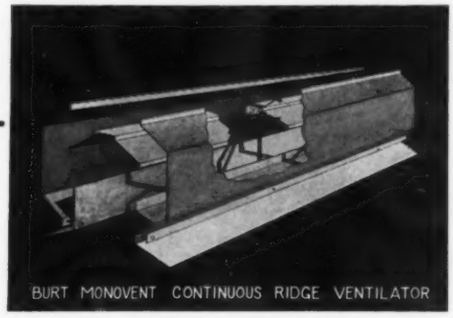
Get the facts about this remarkable process NOW—write for information and catalog No. 212.

THE American FOUNDRY EQUIPMENT CO.

396 S. BYRKIT ST. MISHAWAKA, IND.

BURT

MONOVENT
Continuous Ridge
VENTILATOR


BURT MONOVENT CONTINUOUS RIDGE VENTILATOR

Specially Adapted for Steel Mills

The ventilation of a modern steel mill is no hit-or-miss proposition. Design engineers, through experience, have learned the particular conditions prevailing in each section of the mill. They have learned, too, that no one type of ventilator adequately solves all problems.

In certain sections of the mill there exist sources of heat, which of themselves are sufficient to produce gravity ventilation if the proper roof outlet is provided. Such heat sources are often spread throughout the length of a building, making a uniform outlet extremely advantageous. For these problems, engineers are finding the continuous ridge ventilator an ideal solution.

The Burt Monovent Continuous Ridge Ventilator is presented for such applications with the full assurance that it can and does take the licking which heavy industry gives equipment. It is designed to take full advantage of wind action, to prevent back drafts, to keep free of snow, soot and cinders. It is constructed for ease of installation and operation and for long life and low service. It is supplied in all materials including Asbestos Protected Steel.

Installation references and detailed data will be furnished on request.

THE BURT MFG. CO.

950 South High St., Akron, Ohio

ROOF VENTILATORS — OIL FILTERS — EXHAUST HEADS

QUICK REPAIRS WITHOUT Costly Shutdowns!

IDEAL

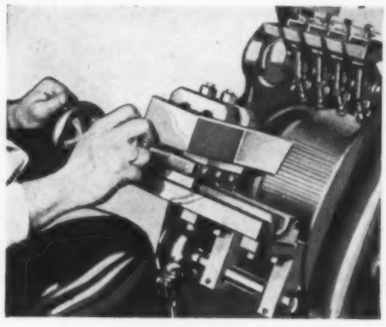
MOTOR MAINTENANCE TOOLS

Don't interrupt production! *Ideal* tools restore commutator and slip rings to original efficiency—with motor right in its own bearings. A precision job—no disassembly necessary.

IDEAL

RESURFACERS

For smoothing up commutators and slip rings which are rough, ridged or scored. No dismantling. No "set up". A type and grade for every job.



IDEAL

PRECISION GRINDERS

Restore badly scored, out-of-round, eccentric and grooved commutators and rings without disassembling motor. Precision work! Mount directly on brush arm or motor frame.

IDEAL

COMMUTATOR SAWS AND CUTTERS

Made by an exclusive *Ideal* process. These Special No. 1 High Speed Steel Saws and milling cutters for undercutting mica, outlast ordinary saws as much as *four-to-one.*

IDEAL

POWER MICA UNDERCUTTER

The smallest, most powerful undercutter built! Cuts down high commutator mica without taking down even the brush rigging! Compact—gets into tight places—cuts within 1/4" of riser.

Write for complete information or ask for demonstration. Complete Hand Book and Catalog upon request
Serving Over 28,000 Users

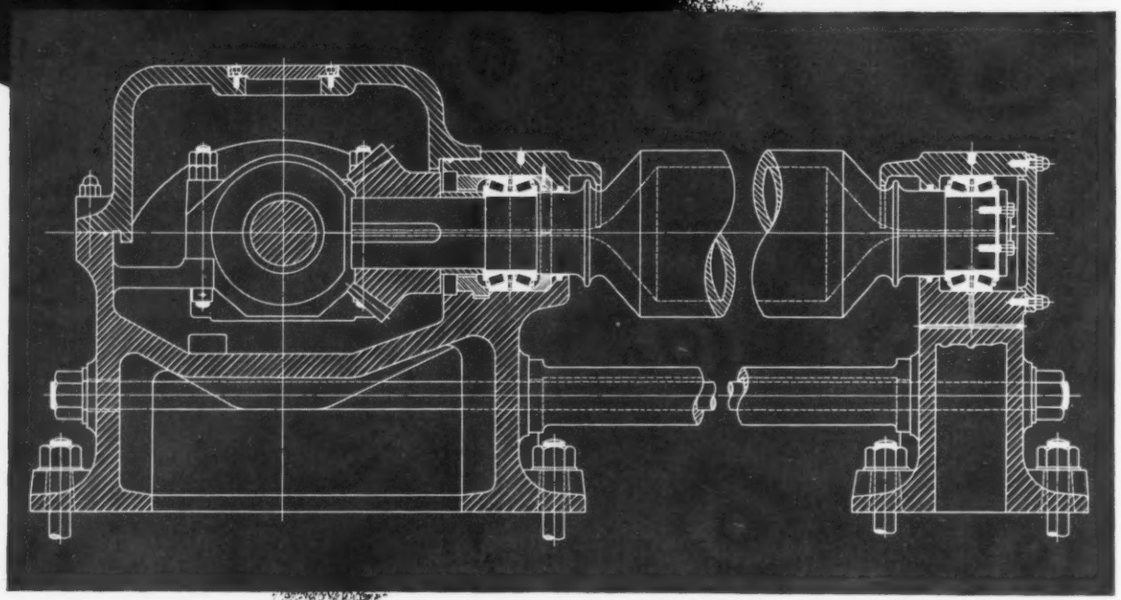
IDEAL COMMUTATOR DRESSER CO.

1045 PARK AVENUE SYCAMORE, ILLINOIS

BRANCHES: PITTSBURGH — CLEVELAND — CHICAGO — NEW YORK

TIMKEN BEARING EQUIPPED TABLE ROLLS KEEP STEEL MOVING AT MODERN TEMPO

Tapered Roller TIMKEN BEARING EQUIPPED



Approach and run-out tables equipped with TIMKEN Tapered Roller Bearings are handling steel regularly at speeds as high as 2,000 feet a minute in modern strip production.

TIMKEN Bearings are especially suited to table roll application because of their inherent ability to carry all loads—radial, thrust or any combination of both—as well as to eliminate friction. Manufactured of TIMKEN Electric Furnace Alloy Steel they have the rugged endurance necessary for long, trouble-free operation in this severe service. The table roll mounting shown here was developed by us and incorporates years of experience and research. This mounting has proved highly successful in many of the steel industry's most important installations. It makes lubrication easy and permits of quick disassembly when necessary. Maintenance cost is consistently low.

When buying new approach, run-out or cooling tables make sure the rolls are equipped with TIMKEN Bearings.

THE TIMKEN ROLLER BEARING COMPANY, CANTON, OHIO

TIMKEN
TAPERED ROLLER BEARINGS

POOLE
Flexible Couplings

FULLY LUBRICATED
DUST PROOF
OIL TIGHT

ALL METAL
NO WELDED PARTS
FREE END FLOAT

It gives full compensation for the unavoidable errors in alignment or those caused by changes of temperature, wear of bearings, vibration, etc. It also permits free lateral float to connected shafts, and prevents torsional motions. Stronger than the connecting shafts. Capable of sudden reversals at high speed or heavy duty, slow speed drives without strain to the coupling or the machinery it connects. Simple in design, no springs, pins or bushings, self-aligning, silent and vibrationless at all times.

Send for a copy of our

Flexible Coupling Handbook

NO. 26 POOLE HEAVY DUTY CAST STEEL MILL TYPE FLEXIBLE COUPLING SHOWN IN ILLUSTRATION ON THE RIGHT.

TOTAL WEIGHT 15 TONS.

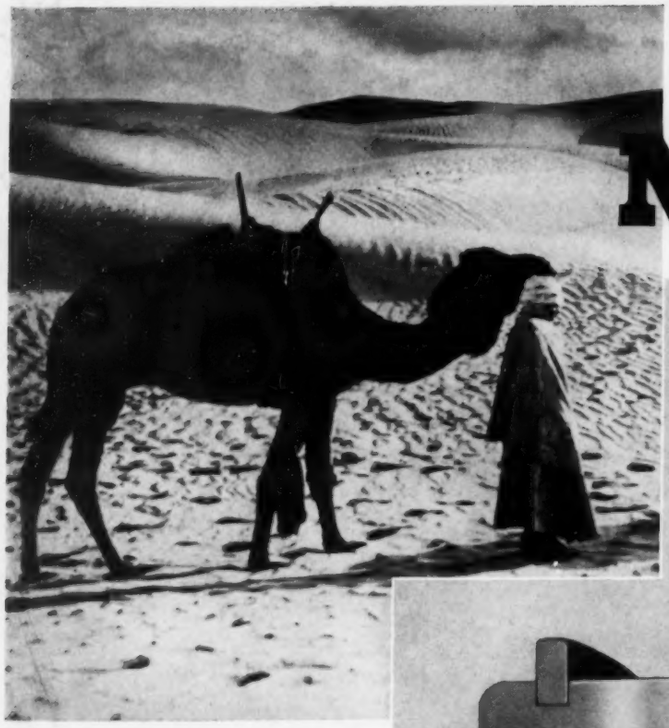
THIS COUPLING USED ON BLOOMING MILL DRIVE

38,000 HP. AT 100 RPM.

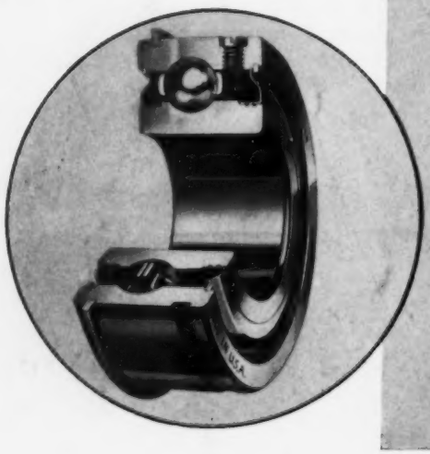
OUTSIDE DIAMETER 77".

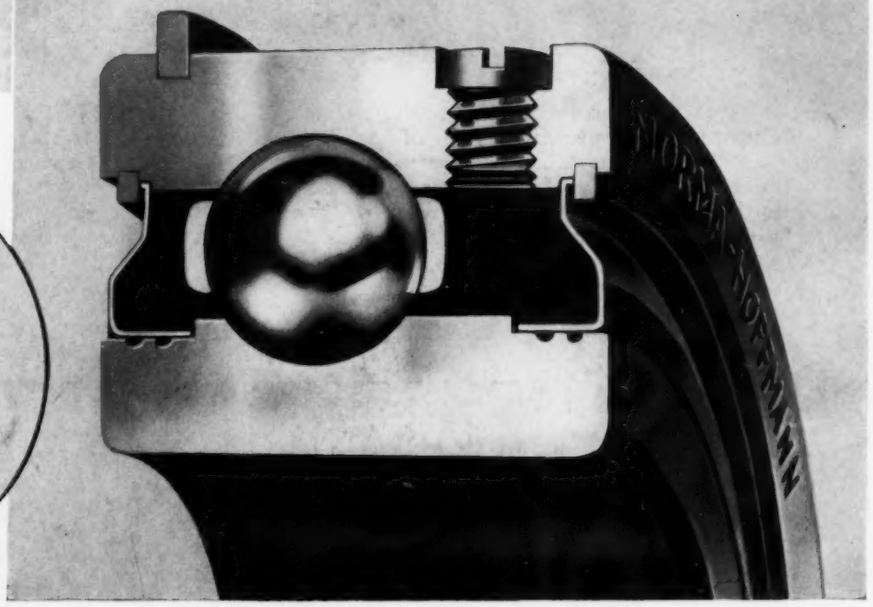
POOLE FOUNDRY & MACHINE COMPANY

BALTIMORE, MARYLAND



NO *Fear of* GOING DRY!





What water means to the camel, lubricant means to a bearing—LIFE ITSELF. And, like the camel, the "CARTRIDGE" BALL BEARING carries within itself its own EXTRA RESERVE SUPPLY, ample for a long period.

In the cross-section herewith, note how its DOUBLE-ROW WIDTH GIVES THE "CARTRIDGE" BEARING DOUBLE THE GREASE CAPACITY of a single-row type. Note also how the in-built metal seals confine the grease WITHIN THE BEARING ITSELF, providing abundant lubrication to the raceways and rotating elements at all times.

The "CARTRIDGE" BALL BEARING is equipped with close-fitting, wearless metal shields which, with recessed inner ring construction and two or more grease grooves, form a truly effective labyrinth through which THE GREASE CANNOT PASS AND DIRT CANNOT ENTER.

Adopt the "CARTRIDGE" BALL BEARING—as your insurance against neglected lubrication, and dirt and grease contamination. It is handled as an integrally sealed unit, unencumbered by any supplementary closure parts. It provides easier and quicker assembly and disassembly. It stays clean before mounting, during assembly, or when removed, and has convenient regreasing and inspection features. Without additional closures, the "CARTRIDGE" BEARING seal is highly effective regardless of the position of the motor or the unit.

Write for the Catalog. Let our engineers work with you.

NORMA-HOFFMANN BEARINGS CORP'N.—STAMFORD, CONN., U. S. A.